

## Article

# Water Demand and Conservation in Arid Urban Environments: Numerical Analysis of Evapotranspiration in Arizona

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## Abstract

Water management in arid regions, such as Arizona, is critical due to increasing demands from the urban, agricultural, and recreational sectors. In this study, Finite element analysis software COMSOL Multiphysics (COMSOL 6.3) is used to quantify water demands in Chandler, Arizona. Evapotranspiration from vegetation and pools is studied. Factors are divided into environmental (temperature, humidity, wind speed) and soil-related properties (moisture content, hydraulic conductivity), which are modeled and used to estimate annual water losses. This study represents the first comprehensive investigation of the usage across several main categories at Arizona. Results indicate that pools contribute 61% of surface water evaporation. Annual water demand in Chandler for 2024 peaks at 425,000 m<sup>3</sup> in June, with irrigation for vegetation dominating consumption. Validation against experimental data confirms model accuracy. This simulation work aims to provide scalable insights for water management in arid urban environments. Based on the simulation, various solutions were proposed to reduce water consumption and minimize water loss. Some active measures include the optimization of irrigation time and frequency based on dynamic and real-time environmental conditions. The proposed solution can help minimize the water consumption while maintaining the water demands for plant life sustenance. Other passive measures include the modification of localized environmental conditions to reduce water evaporation. In particular, it was found that fence installation can significantly change the water vapor flow and distribution close to the water surface and suppress the water evaporation by simply lowering the wind speed right above the water surface. A logical takeaway is that evaporation would also decrease when pools are built with deeper water surfaces.

**Keywords:** water management; finite element analysis; evapotranspiration; pool evaporation; Chandler; Arizona; COMSOL Multiphysics

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## 1. Introduction

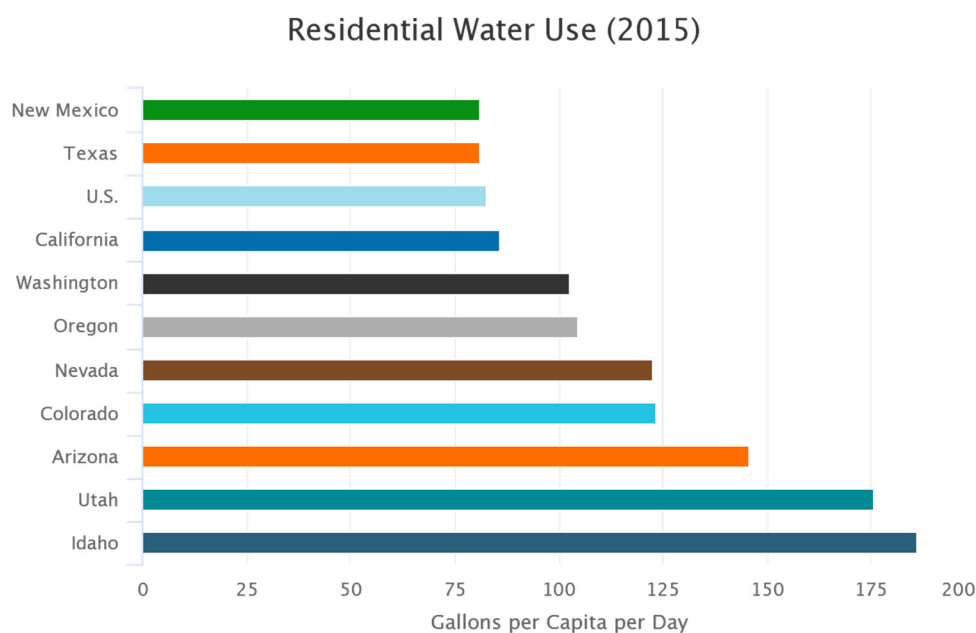
Water scarcity has become a significant bottleneck in economic growth around the world. In the United States Arizona, Nevada, and Southern California continuously fight in courts about the distribution of water from the Colorado River, which no longer empties into the Gulf of California due to heavy water diversion for cities, agriculture, and dams: the diversions dry the river before its delta. Similar legal fights for scarce water are between Florida (Everglades) and Georgia (Atlanta). Also, serious political tensions about the distribution of water from the Jordan River continue between Israel and Jordan.

Similar situations exist in many parts of the world; it will be exacerbated further by population growth, global warming, and climate change.

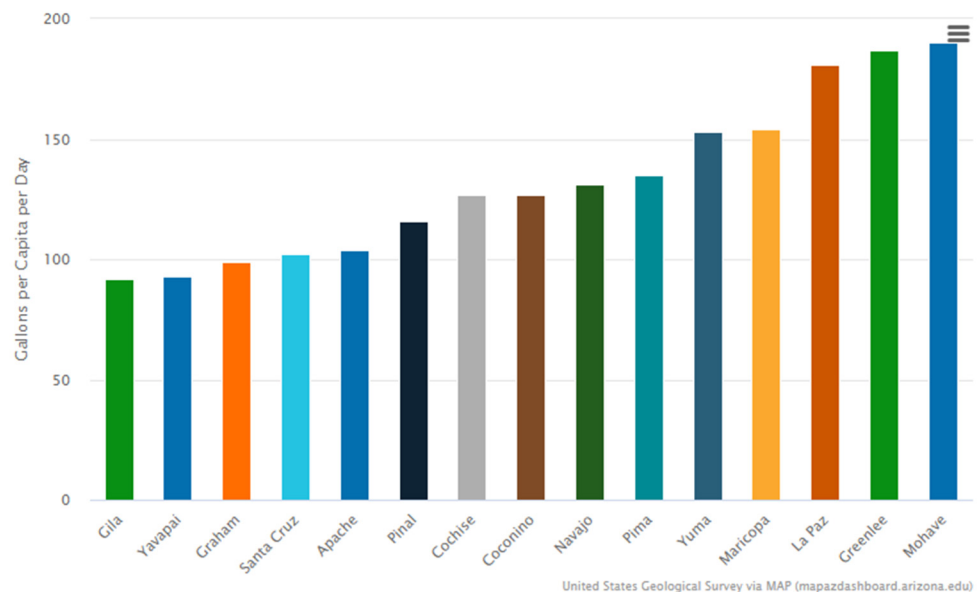
The situation is particularly acute in arid areas. The limits of evaporation and evapotranspiration have been observed, modeled, and studied in numerous papers [1–14]. Some connect the phenomenon to groundwater or soil water depletion [1,5,6,12–16]. Others focus on the connection between the soil moisture content and land–atmosphere exchange dynamics [17]. The methodologies vary widely from experimental [1,18–20], machine learning and neural networks [9–11], numerical modeling [15,16,20,21], to theoretical modeling via percolation theory [1] or a surface energy balance algorithm for land (SEBAL) [22], and more.

Water scarcity is created by the combination of limited resources and demands from urban expansion, agriculture, and recreational facilities. Arizona has an arid climate and rapid population growth, with per capita water use exceeding 140 gallons per day, nearly double the consumption of Texas and California [23]. Reliance falls on groundwater (41%), supplemented by the Colorado River (36%), in-state rivers (18%), and reclaimed water (5%) [24]. In terms of water use, agriculture accounts for 72% of water use, followed by municipal (22%) and industrial (6%) sectors [25]. Over-extraction of groundwater risks aquifer depletion and land subsidence [26,27].

Arizona’s water management strategies, including the 1980 Groundwater Management Act, have established Active Management Areas to regulate groundwater [28]. These efforts position Arizona as a model for sustainable practices in arid regions, so long as they further water recycling and infrastructure development [29]. However, prolonged droughts, climate change, and unregulated groundwater extraction in rural areas continue to stress resources [30,31], such as in Maricopa County, with 62% of Arizona’s population, exhibiting high water consumption, and Chandler, where residential and recreational water use is significant [32]. This said, Arizona can further limit its residential water use, as illustrated in Figures 1 and 2.



**Figure 1.** Gallons per capita per day for 10 US states (U.S. Geological Survey 2015); adapted from Jennifer Pullen, Water Use by Sector Tucson, Arizona MSA, 08-02-2023, posted under the Creative Commons Attribution (CC BY) license at <https://www.mapazdashboard.arizona.edu/article/arizonas-water-use-sector> (accessed on 1 July 2025).



**Figure 2.** Residential water use for Arizona counties (U.S. Geological Survey 2015); adapted from Jennifer Pullen, Water Use by Sector Tucson, Arizona MSA, 08-02-2023, posted under the Creative Commons Attribution (CC BY) license at <https://www.mapazdashboard.arizona.edu/article/arizonas-water-use-sector> (accessed on 1 July 2025).

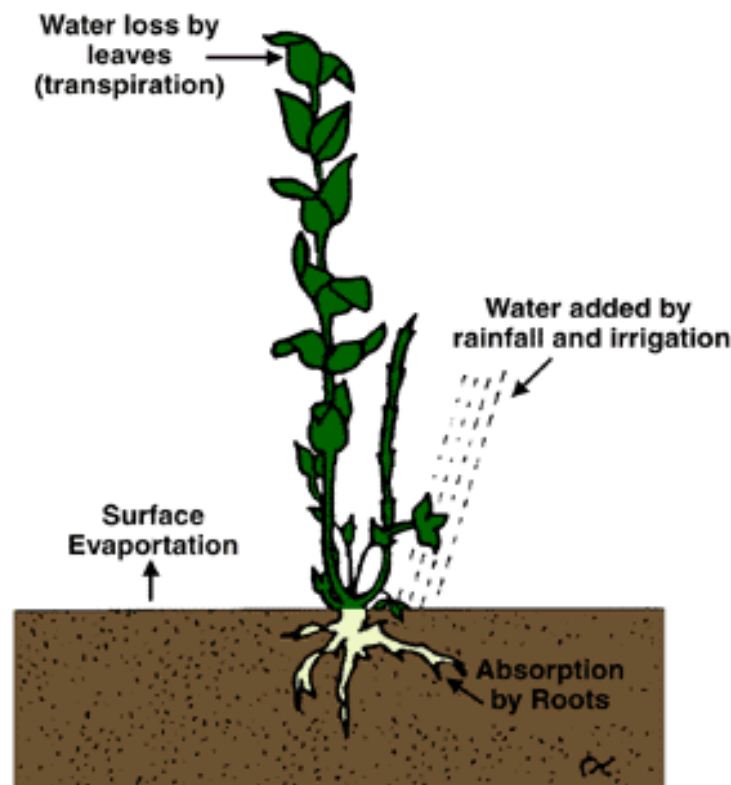
This study focuses on Chandler, a typical city in Maricopa County. Chandler serves as an excellent baseline city due to its position in the southeastern Phoenix metropolitan area. ET, encompassing soil evaporation and plant transpiration, is influenced by environmental factors (temperature, humidity, wind speed, solar radiation) and soil properties (moisture content, hydraulic conductivity) [33,34]. Pool evaporation, driven by similar environmental conditions, is significant in Arizona's hot, arid climate [35]. While the city publishes water usage data every year, there is no categorized data about how the water is consumed. This makes the prediction of future water usage challenging. Using COMSOL Multiphysics, a finite element analysis tool, this study models these processes to estimate daily and annual water demands for several main water consumption categories (pool and vegetation), providing insights for conservation strategies. Different from other simulation tools, COMSOL Multiphysics can combine multiple physics models to perform complex real-world simulations including various environmental conditions and human designs. The simulation can provide good guidance on how to improve water conservation strategies.

Although there are already papers discussing different types of water conservation strategies [2–4,36,37], they mainly focus on how to develop water conservation technology. There is a gap in understanding the fundamental physics behind the technology. By combining multiple physics models together, COMSOL Multiphysics can provide more specific validation and compare the effect of different measures based on the simulation of physics models behind. Finally, COMSOL Multiphysics has been successfully used in peer-reviewed studies [15,16,38–42]. This software is a reasonable, highly accurate alternative to HYDRUS, which is, perhaps, more popular for modeling vadose zone fluxes [20,21].

There are five main objectives to this study which are to model evapotranspiration for vegetation; quantify pool evaporation; estimate hourly, monthly, and annual water demands in Chandler; analyze historical trends (2014–2024); and propose conservation strategies.

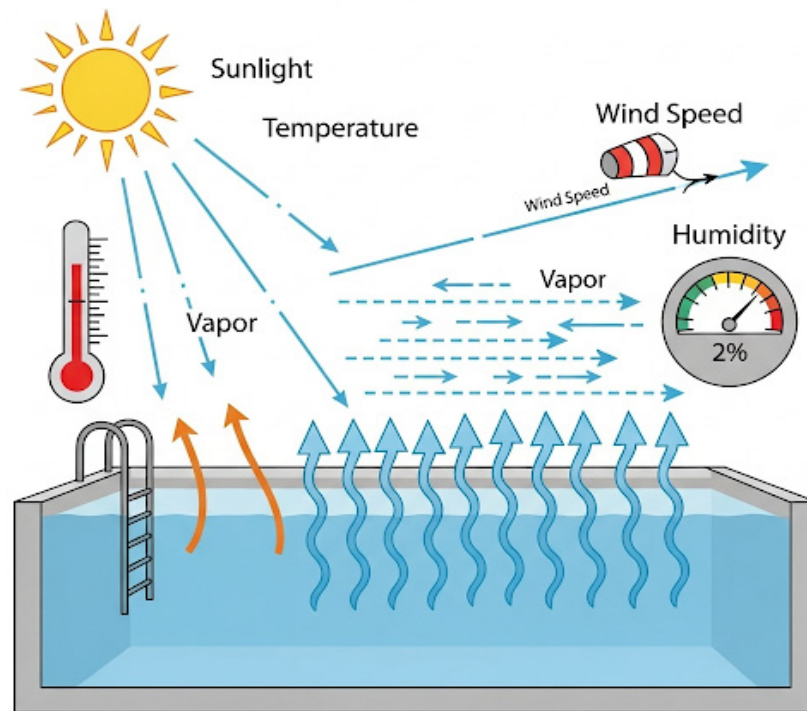
### *Problem Statement*

Arizona's water scarcity is projected to intensify due to climate change, population growth, and diminishing surface water availability [37]. With limited prospects for new water sources, conservation is critical. Vegetation (trees, grass) and pools are significant water consumers in residential and public spaces, with losses driven by evapotranspiration (connected through the vadose zone to groundwater [37]) and evaporation, respectively. Understanding the minimum water required to sustain plant life and maintain pool levels is essential for optimizing irrigation and reducing waste [1,36]. The schematic of water consumption by plant-covered ground is presented in Figure 3.



**Figure 3.** Water consumption of plant-covered ground (www. tamu.edu: Efficient Use of Water in the Garden and Landscape); adapted from Larry Stein and Doug Welsh, Efficient Use of Water in the Garden and Landscape, posted under the Creative Commons Attribution (CC BY) license at <https://aggie-horticulture.tamu.edu/earthkind/drought/efficient-use-of-water-in-the-garden-and-landscape/> (accessed on 1 July 2025).

This study employs COMSOL Multiphysics to simulate water loss from pools and vegetation in Chandler, considering environmental factors (temperature, humidity, wind speed) and soil properties. In Figure 4 we present a schematic of the processes involved and factors affecting them. The figure was generated with the assistance of Google Gemini 2.5 Pro. The goals are to (1) quantify daily minimum water demands for vegetation and pools; (2) estimate annual demands by scaling daily results; (3) analyze hourly and monthly water loss variations; (4) evaluate historical trends; and (5) propose strategies to minimize water loss while maintaining functionality.



**Figure 4.** Water evaporation from a pool (image generated by Google Gemini 2.5 Pro).

## 2. Materials and Methods

### 2.1. Finite Element Analysis

Finite element analysis using COMSOL Multiphysics (version 6.0) [38] was employed to model water loss from pools and vegetation. COMSOL's ability to couple multiple physics interfaces (heat transfer, subsurface flow, moisture transport, fluid dynamics) enables accurate simulation of complex interactions in the soil–plant–atmosphere continuum and air–water interfaces. Daily water losses were scaled to estimate annual demands, providing insights for regional water management.

COMSOL Multiphysics is a software that can simulate designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. The COMSOL Model Builder includes all the steps in the modeling workflow, including defining geometries, material properties, and the physics that describe specific phenomena to perform computations and evaluate the results. The accuracy of COMSOL simulations is largely based on the setup (discretization) and input parameters. As already mentioned, COMSOL has been widely used in peer-reviewed studies [15,16,38–42] and can provide efficient ways to simulate real physics processes.

### 2.2. Model Setup

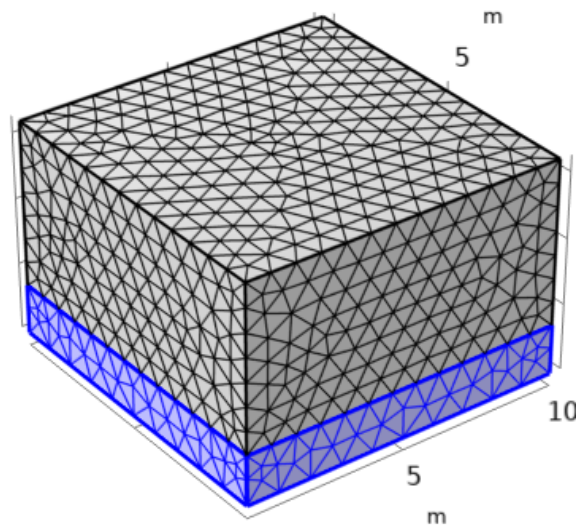
There are two different simulation frameworks in this study: pool evaporation and vegetation irrigation. The pool evaporation framework simulated heat transfer in fluids for air and water, with boundary temperatures and convective heat flux; (2) transport of diluted species for water vapor, with defined diffusion coefficients and vapor flux at the water surface; (3) laminar flow to model wind, with inlet wind speed, outlet pressure (0 Pa gauge), and open boundary conditions; (4) multiphysics coupling for evaporation via boundary flux [42,43].

Vegetation irrigation uses (1) heat transfer module for temperature distribution in soil, plants, air, and pool water; (2) subsurface flow module using Richards' equation for soil water movement and root water uptake; (3) moisture transport in air for evaporation and transpiration; (4) CFD Module for airflow over surfaces [44,45].

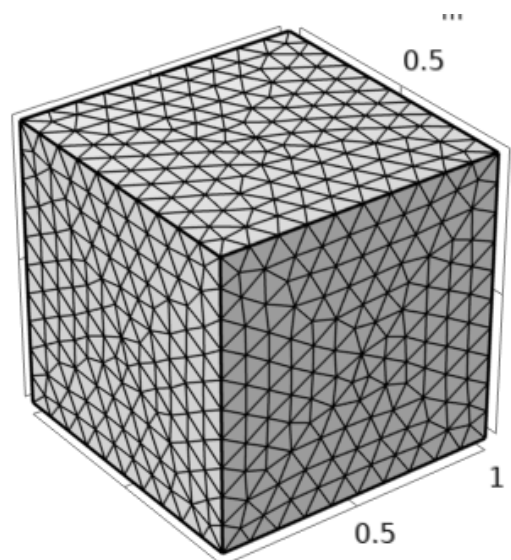
The basic input COMSOL Multiphysics files used in this study are available in the Supplementary Material.

### 2.3. Geometry

Geometries were defined for a representative pool ( $4\text{ m} \times 8\text{ m} \times 2\text{ m}$ ) and a grass-covered area ( $1\text{ m}^2$ ), based on typical dimensions in Chandler [46]. Figures 5 and 6 show the meshed 3D models of a pool and a grass-covered area.



**Figure 5.** COMSOL generated pool geometry.



**Figure 6.** COMSOL generated grass irrigation geometry.

### 2.4. Material Properties

Material properties for water, air, soil, and vegetation mainly came from the integrated material database in COMSOL. Some material parameters were sourced from the literature, including hydraulic conductivity, water retention curves, and temperature-dependent air viscosity [47,48]. The summary of these parameters is presented in Figures 7 and 8.

| Property                       | Variab   | Value      | Unit              |
|--------------------------------|----------|------------|-------------------|
| Thermal conductivity           | k_iso... | k(T)       | W/(m·K)           |
| Specific gas constant          | Rs       | 461.5[J... | J/(kg·K)          |
| Heat capacity at constant p... | Cp       | 1859[J/... | J/(kg·K)          |
| Coefficient of thermal expa... | alpha... | alpha_...  | 1/K               |
| Bulk viscosity                 | muB      | muB(T)     | Pa·s              |
| Dynamic viscosity              | mu       | eta(T)     | Pa·s              |
| Ratio of specific heats        | gam...   | gamm...    | 1                 |
| Electrical conductivity        | sigm...  | 5.5e-6[... | S/m               |
| Heat capacity at constant p... | Cp       | Cp(T)      | J/(kg·K)          |
| Density                        | rho      | rho(T)     | kg/m <sup>3</sup> |
| Speed of sound                 | c        | cs(T)      | m/s               |
| Ratio of specific heats        | gam...   | 1.33       | 1                 |
| Mean molar mass                | Mn       | 0.0180...  | kg/mol            |

**Figure 7.** Pool material properties in COMSOL. Note that COMSOL uses the Fortran notation rather than scientific notation, e.g., “8e3” rather than “ $8 \times 10^3$ ”. The COMSOL notation is more suitable for numerical results as it specifies the numerical precision, e.g., 8E3 is single precision and 8D3 is double precision.

| Property                       | Variab   | Value      | Unit              |
|--------------------------------|----------|------------|-------------------|
| Density                        | rho      | 1500       | kg/m <sup>3</sup> |
| Dynamic viscosity              | mu       | 1e-3       | Pa·s              |
| Porosity                       | epsilon  | 0.45       | 1                 |
| Permeability                   | kapp...  | 1e-12      | m <sup>2</sup>    |
| Heat capacity at constant p... | Cp       | 4180[J/... | J/(kg·...         |
| Thermal conductivity           | k_iso... | 1.2        | W/(m...           |
| Compressibility of fluid       | chif     | 1e-9       | 1/Pa              |

**Figure 8.** Grass irrigation material properties in COMSOL. Note that COMSOL uses the Fortran notation rather than scientific notation, e.g., “8e3” rather than “ $8 \times 10^3$ ”. The COMSOL notation is more suitable for numerical results as it specifies the numerical precision, e.g., 8E3 is single precision and 8D3 is double precision.

## 2.5. Data Collection

Data was sourced from Chandler’s government database for water and plant coverage, supplemented by satellite imagery [49]. Environmental data (temperature, humidity, wind speed) were obtained for 2024, with hourly data for 1 August 2024, and monthly averages [50]. Historical weather data (2014–2024) were used to analyze trends [51].

Water coverage (rivers, lakes, pools) and plant coverage (trees, grass) were estimated using satellite imagery—Figure 9 presents Chandler city satellite map—and municipal records [52]. COMSOL simulations analyzed water loss due to evaporation and consumption by vegetation, considering environmental impacts and soil properties [53].

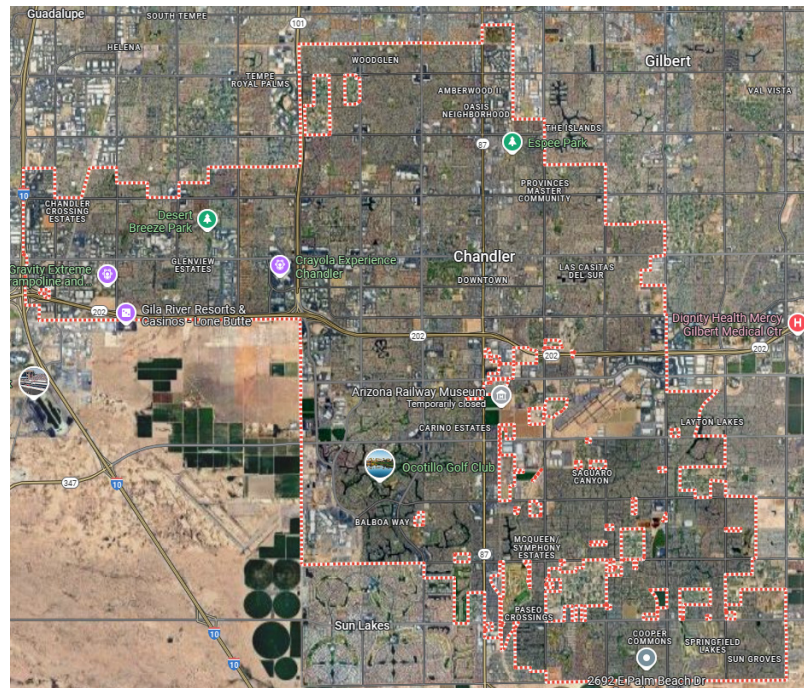


Figure 9. Chandler city satellite map (Google Maps).

### 3. Results

#### 3.1. Pool Water Evaporation

Simulations quantified pool evaporation under varying environmental conditions. The pressure profile (Figure 10) for the pool–air system showed higher pressure at the water surface due to evaporation, decreasing with height as vapor diffuses (Figure 11) into the air [54].

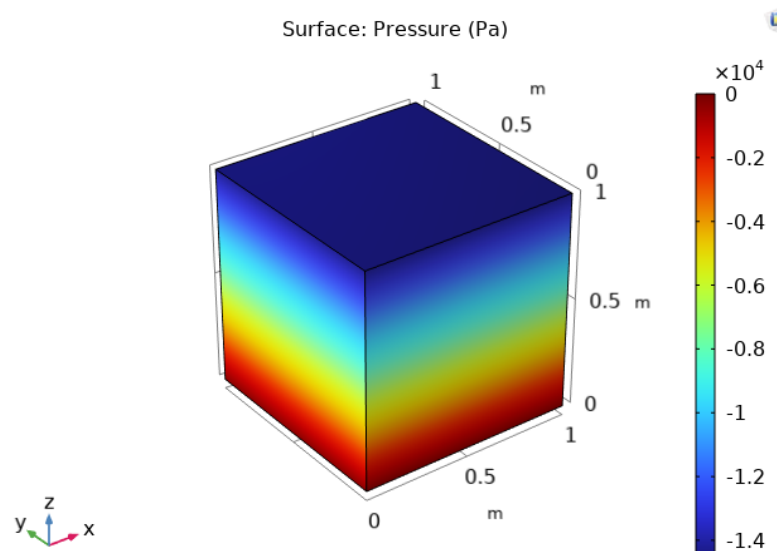
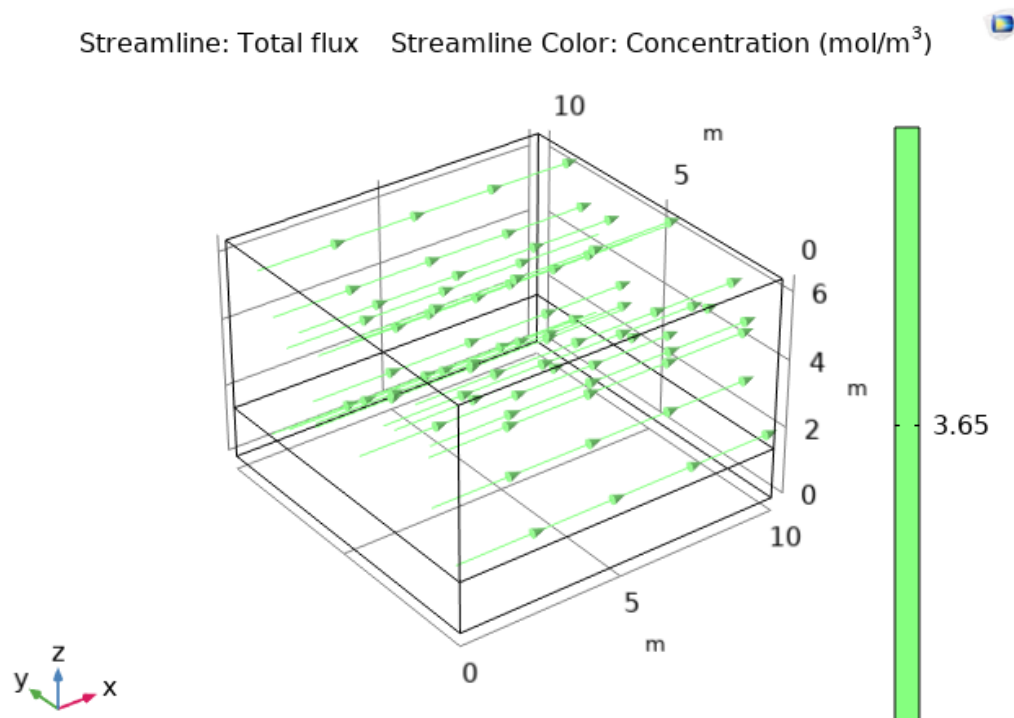


Figure 10. COMSOL simulated 3D pressure profile for pool–air system.



**Figure 11.** COMSOL simulated concentration streamline.

A design of experiment with 13 runs evaluated the impact of temperature, wind speed, and humidity on evaporation rates. In the simulation, a pool with a size of 10 m × 10 m × 1.5 m was built. To simulate the environment impact, an air box with size of 10 m × 10 m × 10 m was configured above the pool. Then different combinations of temperature, relative humidity, and wind speed were applied in the COMSOL model to calculate the water loss due to evaporation—see Table 1.

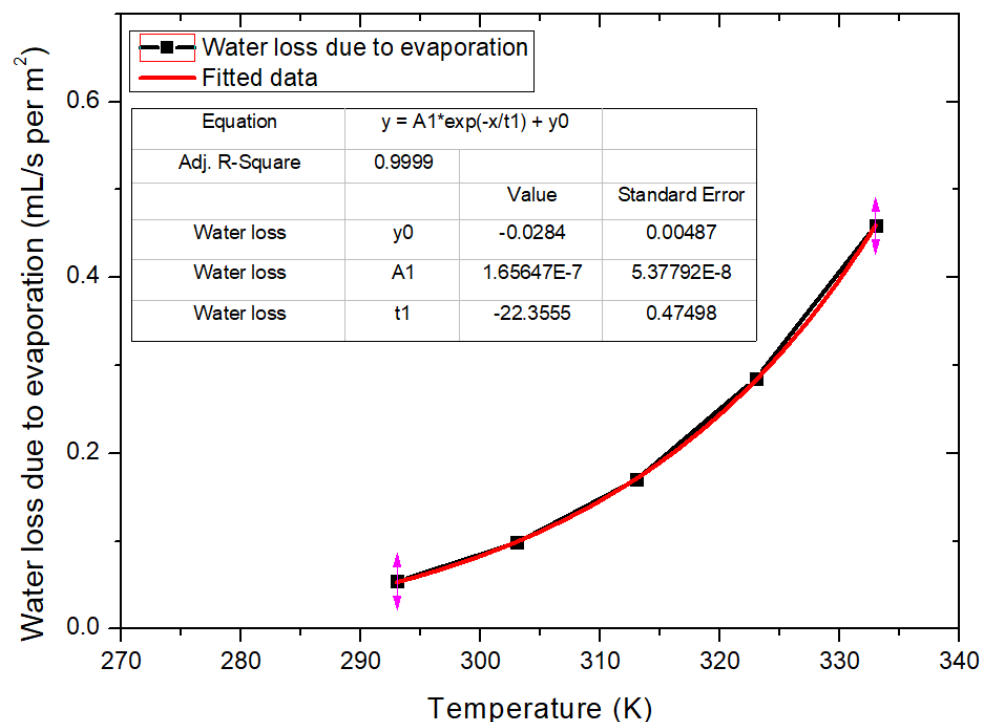
**Table 1.** Design of experiment conditions for water evaporation loss.

| Test | Pool Size (L × W × H) | Air Size (L × W × H) | Temperature (K) | Wind Speed (m/s) | Relative Humidity | Water Loss Due to Evaporation (mL/s per m <sup>2</sup> ) |
|------|-----------------------|----------------------|-----------------|------------------|-------------------|----------------------------------------------------------|
| D01  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 293             | 10               | 0.1               | 0.054                                                    |
| D02  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 303             | 10               | 0.1               | 0.098165                                                 |
| D03  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 313             | 10               | 0.1               | 0.17                                                     |
| D04  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.1               | 0.285                                                    |
| D05  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 333             | 10               | 0.1               | 0.459                                                    |
| D06  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 1                | 0.1               | 0.09                                                     |
| D07  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 2                | 0.1               | 0.127                                                    |
| D08  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 5                | 0.1               | 0.2                                                      |
| D09  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.1               | 0.285                                                    |
| D10  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.1               | 0.285                                                    |
| D11  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.2               | 0.253                                                    |
| D12  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.5               | 0.158                                                    |
| D13  | 10 m × 10 m × 1.5 m   | 10 m × 10 m × 10 m   | 323             | 10               | 0.8               | 0.063                                                    |

### 3.1.1. Temperature Impact

Temperature is the main factor of evaporation. At 303 K, the evaporation rate was 0.1 mL/s/m<sup>2</sup>, increasing to 0.2 mL/s/m<sup>2</sup> at 313 K and 0.3 mL/s/m<sup>2</sup> at 322 K, reflecting Chandler's

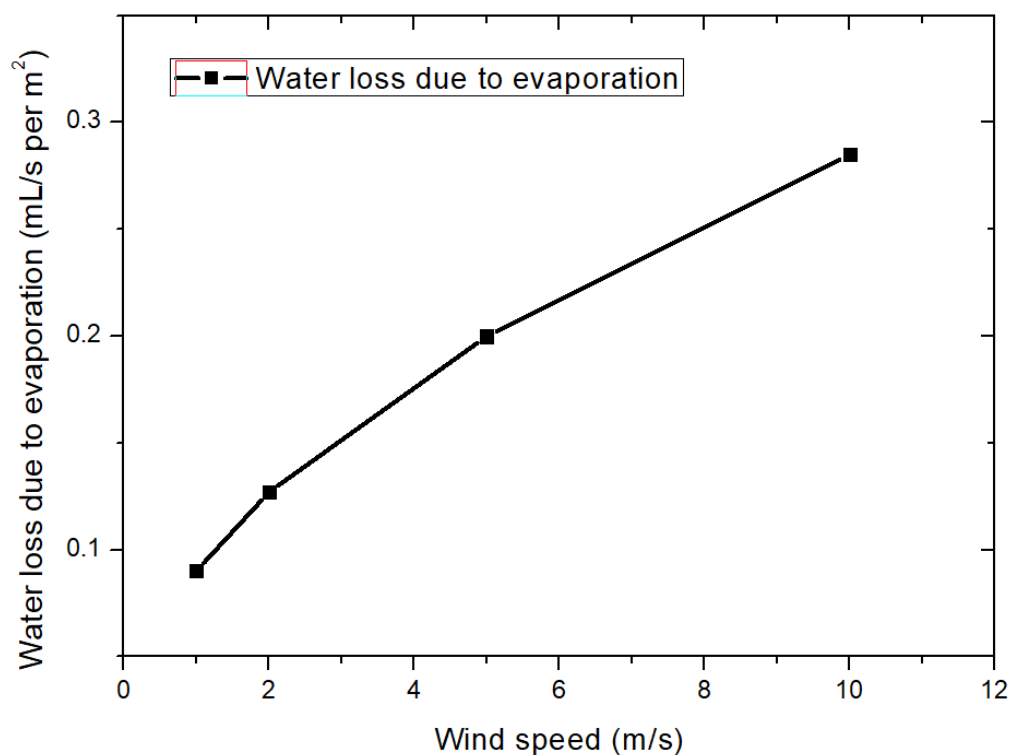
peak summer temperatures [55]. The relationship is nonlinear, with greater sensitivity at higher temperatures [56]—see Figure 12.



**Figure 12.** COMSOL simulated temperature impact on the pool water loss rate.

### 3.1.2. Wind Speed Impact

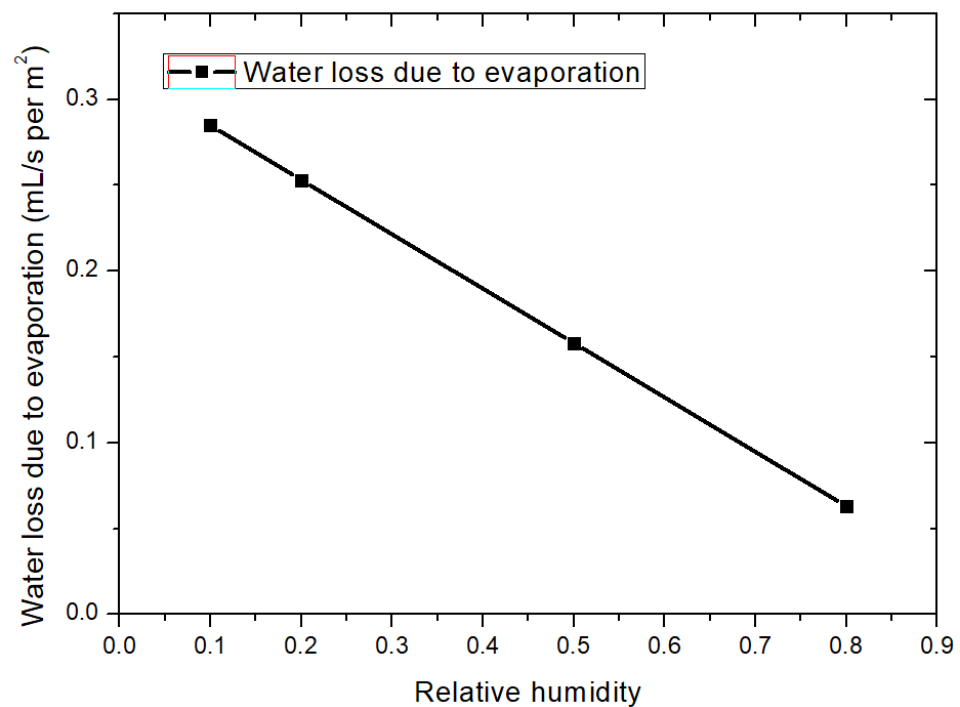
Wind speed affects evaporation, with rates increasing from 0.09 mL/s/m<sup>2</sup> at 1 m/s to 0.285 mL/s/m<sup>2</sup> at 10 m/s [57]. The effect stabilizes at higher wind speeds, suggesting a saturation point [35]—see Figure 13.



**Figure 13.** COMSOL simulated wind speed impact on the pool water loss rate.

### 3.1.3. Humidity Impact

Relative humidity exhibits a linear inverse relationship with evaporation. As humidity rises from 10% to 50%, the evaporation rate decreases from 0.285 mL/s/m<sup>2</sup> to 0.158 mL/s/m<sup>2</sup>, as higher atmospheric moisture suppresses evaporation [58,59]—see Figure 14.



**Figure 14.** COMSOL simulated relative humidity impact on the pool water loss rate.

Arizona generally experiences a hot and arid climate, particularly in its lower elevations. Average summer temperatures often exceed 38 °C (100 °F), while winter daytime temperatures are typically in the range of 15 °C to 20 °C (59 °F to 68 °F). Humidity levels are consistently very low across the state, with annual averages around 40% and often dropping to single digits during the hottest months. Wind speeds are generally light to moderate, with averages typically ranging from 2.2 m/s to 3.6 m/s (5 to 8 mph), though localized conditions can lead to higher gusts. Higher temperatures and low humidity both cause more water loss [60]. This makes Arizona one of the states with the highest water usage and water demand. Unfortunately, as a desert state, Arizona has very limited water resources. Historically, 41% of Arizona's water resources come from groundwater.

### 3.2. Annual Water Loss Due to Evaporation

Chandler's total pool surface area was estimated at 29,682,450 ft<sup>2</sup> (0.11 mi<sup>2</sup>), based on 114,219 housing units, 55% with pools (average size 450 ft<sup>2</sup>), plus a 5% allowance for commercial pools [61]. Combined with other water bodies (0.07 mi<sup>2</sup>), the total water surface area is 0.18 mi<sup>2</sup> [62]—see Table 2.

**Table 2.** Chandler total water surface area.

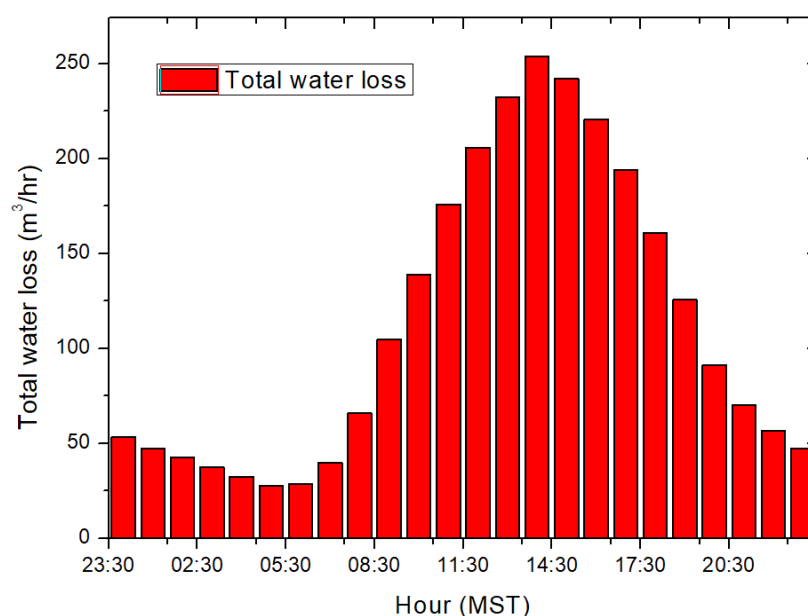
|                    | Water Resources (Lake, River) | Pools             |
|--------------------|-------------------------------|-------------------|
| Water surface area | 0.07 square miles             | 0.11 square miles |

#### 3.2.1. Hourly Water Loss

Arizona summer has significant weather variation from day to night [63]. This causes water loss rate change with time. Table 3 shows the temperature, wind speed, and relative humidity data within 24 h during the hottest day in Chandler. The weather conditions were then introduced into COMSOL physics models. It is observed that the water loss rate changes with time. At 2pm, water evaporation loss was the highest (0.5447 L/m<sup>2</sup>/h) and 5am had the lowest water evaporation loss (0.0592 L/m<sup>2</sup>/h). The Chandler water loss amount in 24 h can be obtained by multiplying the water loss rate by Chandler water surface area. Figure 15 shows the bar chart of Chandler water loss amount in 24 h. At 2 pm, the whole Chandler city lost 250 m<sup>3</sup> water due to evaporation. But at 5 am, the city only lost 25 m<sup>3</sup> of water, which is 10 times less than the maximum value at 2 pm [64].

**Table 3.** COMSOL simulated water loss during the hottest day in Chandler, AZ (estimated hourly data for 1 August 2024).

| Hour  | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Loss (L/(m <sup>2</sup> ·h)) | Hour  | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Loss (L/(m <sup>2</sup> ·h)) |
|-------|-------------------------|------------------|--------------|------------------------------------|-------|-------------------------|------------------|--------------|------------------------------------|
| 0:00  | 302.04                  | 2.24             | 35           | 0.11429                            | 12:00 | 316.48                  | 4.02             | 15           | 0.44143                            |
| 1:00  | 301.48                  | 2.01             | 37           | 0.10158                            | 13:00 | 317.59                  | 4.47             | 14           | 0.49873                            |
| 2:00  | 300.93                  | 1.79             | 38           | 0.09136                            | 14:00 | 318.15                  | 4.92             | 13           | 0.54474                            |
| 3:00  | 300.37                  | 1.56             | 40           | 0.07988                            | 15:00 | 318.15                  | 4.47             | 13           | 0.51923                            |
| 4:00  | 299.82                  | 1.34             | 42           | 0.06929                            | 16:00 | 317.59                  | 4.02             | 14           | 0.47296                            |
| 5:00  | 299.26                  | 1.12             | 44           | 0.05917                            | 17:00 | 316.48                  | 3.58             | 15           | 0.41658                            |
| 6:00  | 298.71                  | 1.34             | 45           | 0.06153                            | 18:00 | 314.82                  | 3.13             | 18           | 0.34461                            |
| 7:00  | 301.48                  | 1.56             | 40           | 0.08523                            | 19:00 | 312.59                  | 2.68             | 22           | 0.26957                            |
| 8:00  | 305.37                  | 2.01             | 30           | 0.14101                            | 20:00 | 309.82                  | 2.24             | 28           | 0.19594                            |
| 9:00  | 309.26                  | 2.68             | 22           | 0.22519                            | 21:00 | 307.04                  | 2.01             | 32           | 0.15041                            |
| 10:00 | 312.04                  | 3.13             | 18           | 0.29739                            | 22:00 | 304.82                  | 1.79             | 34           | 0.12163                            |
| 11:00 | 314.82                  | 3.58             | 16           | 0.37754                            | 23:00 | 303.15                  | 1.56             | 35           | 0.10167                            |



**Figure 15.** COMSOL simulated chandler water loss amount in 24 hours.

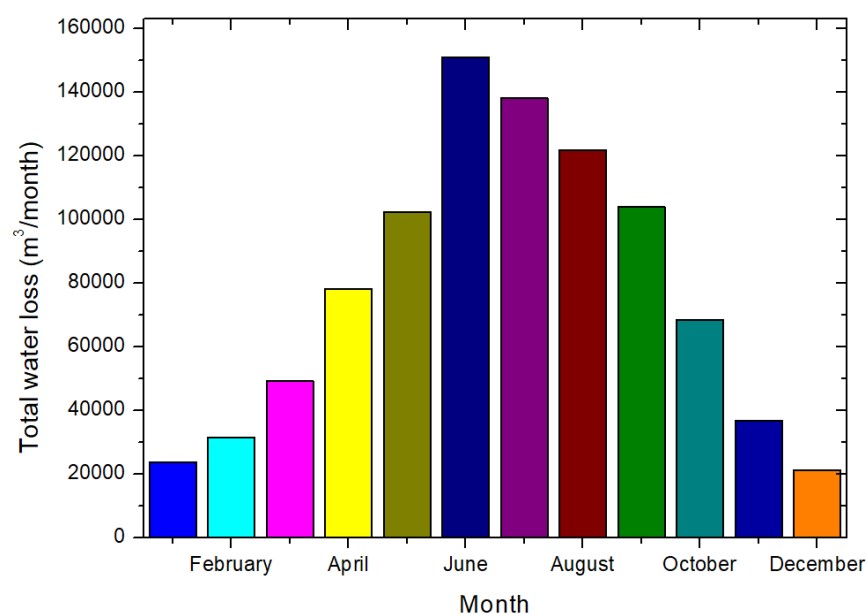
### 3.2.2. Monthly Water Loss (2024)

To understand the water loss across the year, COMSOL simulation was performed to calculate the water loss rate from January to December of 2024. June has the highest water loss rate of 323.7 L/m<sup>2</sup>. This is attributed to the high temperatures (313.15 K) and low humidity (17%) [65]. Although July has an even higher temperature of 313.7 K, its relative humidity (29) is much higher than June (17). This results in a relatively lower water loss rate of 295.97 L/m<sup>2</sup> for July [66]—see Table 4.

**Table 4.** COMSOL simulated water loss due to evaporation in 12 months of 2024 in Chandler, AZ.

| Month     | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Loss (L/(m <sup>2</sup> ·month)) |
|-----------|-------------------------|------------------|--------------|----------------------------------------|
| January   | 292.59                  | 3.58             | 46           | 50.6213                                |
| February  | 294.26                  | 4.47             | 42           | 67.3787                                |
| March     | 298.71                  | 4.92             | 34           | 105.2724                               |
| April     | 302.59                  | 5.81             | 23           | 167.466                                |
| May       | 306.48                  | 5.81             | 19           | 219.6725                               |
| June      | 313.15                  | 5.81             | 17           | 323.7458                               |
| July      | 313.7                   | 6.26             | 29           | 295.9689                               |
| August    | 313.15                  | 5.81             | 33           | 261.3369                               |
| September | 310.37                  | 5.36             | 31           | 222.6675                               |
| October   | 304.26                  | 4.47             | 30           | 146.9284                               |
| November  | 297.04                  | 3.58             | 36           | 78.8037                                |
| December  | 291.48                  | 3.58             | 48           | 45.4706                                |

Similarly, multiplying above water loss rate by the total water surface area in Chandler, the total water loss by month can be calculated. Figure 16 shows the bar chart of the calculated water loss data. In the hottest month of June, Chandler lost 150,000 m<sup>3</sup> of water due to evaporation from all kinds of water resources (pools, rivers, lakes). Among the total water loss, 61% of water loss is due to pools [67]. Preserving pool water becomes a very challenging problem for cities like Chandler.



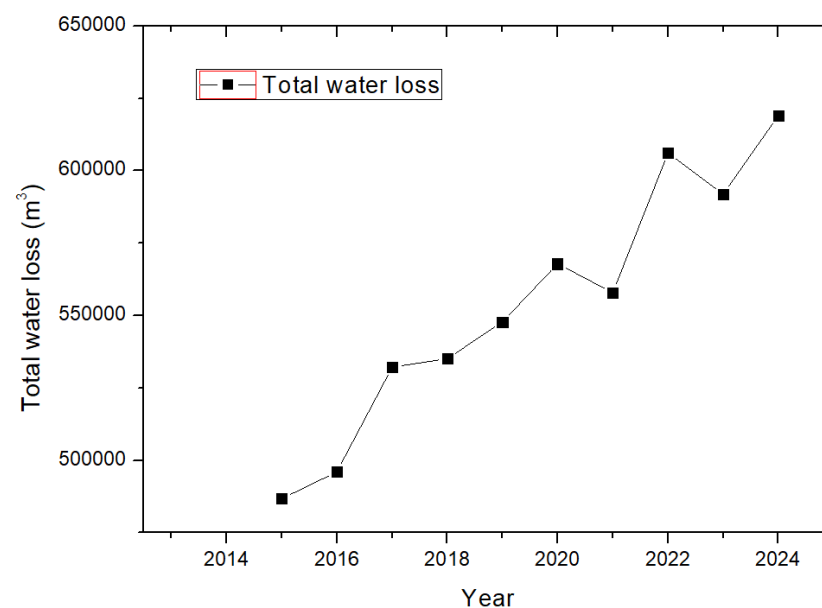
**Figure 16.** COMSOL simulated Chandler water loss amount by month in 2024.

### 3.2.3. Annual Water Loss (2014–2024)

Table 5 shows the weather changes in past 10 years. COMSOL simulation was performed based on these conditions. The result is summarized in Figure 17. Simulations over the past decade showed a 2.5-fold increase in annual water loss, from 1043.99 L/m<sup>2</sup> in 2014 to 1327.78 L/m<sup>2</sup> in 2024, driven by a 3 K temperature increase and decreasing humidity [68,69]. This trend underscores the impact of global warming on water resources [70].

**Table 5.** COMSOL simulated water loss based on annual average weather data for Chandler, AZ (past 10 years).

| Year | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Loss (L/(m <sup>2</sup> ·Year)) |
|------|-------------------------|------------------|--------------|---------------------------------------|
| 2015 | 296.7                   | 3.8              | 30           | 1043.9916                             |
| 2016 | 297                     | 3.7              | 29           | 1063.9472                             |
| 2017 | 297.5                   | 3.9              | 28           | 1141.4933                             |
| 2018 | 297.8                   | 3.7              | 27           | 1147.7199                             |
| 2019 | 298.2                   | 3.8              | 28           | 1174.931                              |
| 2020 | 298.8                   | 3.6              | 26           | 1218.0722                             |
| 2021 | 298.5                   | 3.7              | 27           | 1196.6635                             |
| 2022 | 299                     | 3.9              | 25           | 1300.273                              |
| 2023 | 299.5                   | 3.6              | 26           | 1269.5961                             |
| 2024 | 299.8                   | 3.7              | 25           | 1327.7776                             |



**Figure 17.** COMSOL simulated Chandler water loss amount by year in past 10 years.

### 3.3. Vegetation Water Demand

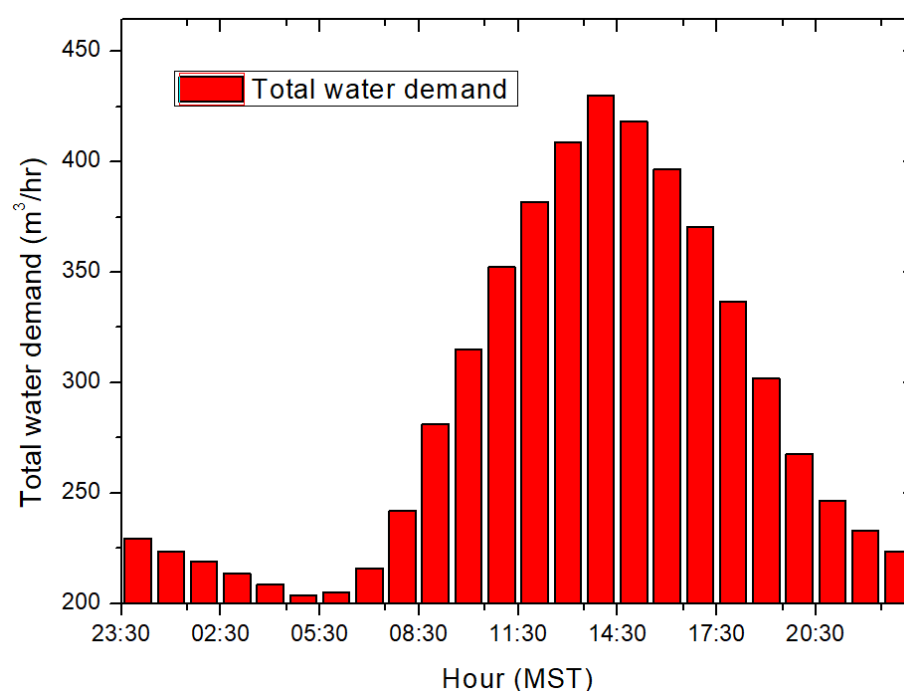
Vegetation water demand was modeled assuming grass coverage for simplicity, with a total plant-covered area of 23 mi<sup>2</sup> (35% of Chandler's 65.48 mi<sup>2</sup> land area) [71]. This includes parks (3.7%), agricultural land (8%), residential landscaping (60%), and commercial areas (28.3%) [72]. Water demand comprises soil evaporation and plant uptake, influenced by environmental conditions [73].

### 3.3.1. Hourly Water Demand

Hourly simulations for 1 August 2024 showed peak water demand at 14:00 (0.9227 L/m<sup>2</sup>/h), totaling 425 m<sup>3</sup>, driven by high temperatures and low humidity [74]. Minimum demand occurred at 05:00 (0.4372 L/m<sup>2</sup>/h) [75]. The simulation results are summarized in Table 6 and Figure 18.

**Table 6.** COMSOL simulated water demand during hottest day in Chandler, AZ (estimated hourly data for 1 August 2024).

| Hour  | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Demand (L/(m <sup>2</sup> ·h)) | Hour  | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Demand (L/(m <sup>2</sup> ·h)) |
|-------|-------------------------|------------------|--------------|--------------------------------------|-------|-------------------------|------------------|--------------|--------------------------------------|
| 0:00  | 302.04                  | 2.24             | 35           | 0.49229                              | 12:00 | 316.48                  | 4.02             | 15           | 0.81943                              |
| 1:00  | 301.48                  | 2.01             | 37           | 0.47958                              | 13:00 | 317.59                  | 4.47             | 14           | 0.87673                              |
| 2:00  | 300.93                  | 1.79             | 38           | 0.46936                              | 14:00 | 318.15                  | 4.92             | 13           | 0.92274                              |
| 3:00  | 300.37                  | 1.56             | 40           | 0.45788                              | 15:00 | 318.15                  | 4.47             | 13           | 0.89723                              |
| 4:00  | 299.82                  | 1.34             | 42           | 0.44729                              | 16:00 | 317.59                  | 4.02             | 14           | 0.85096                              |
| 5:00  | 299.26                  | 1.12             | 44           | 0.43717                              | 17:00 | 316.48                  | 3.58             | 15           | 0.79458                              |
| 6:00  | 298.71                  | 1.34             | 45           | 0.43953                              | 18:00 | 314.82                  | 3.13             | 18           | 0.72261                              |
| 7:00  | 301.48                  | 1.56             | 40           | 0.46323                              | 19:00 | 312.59                  | 2.68             | 22           | 0.64757                              |
| 8:00  | 305.37                  | 2.01             | 30           | 0.51901                              | 20:00 | 309.82                  | 2.24             | 28           | 0.57394                              |
| 9:00  | 309.26                  | 2.68             | 22           | 0.60319                              | 21:00 | 307.04                  | 2.01             | 32           | 0.52841                              |
| 10:00 | 312.04                  | 3.13             | 18           | 0.67539                              | 22:00 | 304.82                  | 1.79             | 34           | 0.49963                              |
| 11:00 | 314.82                  | 3.58             | 16           | 0.75554                              | 23:00 | 303.15                  | 1.56             | 35           | 0.47967                              |



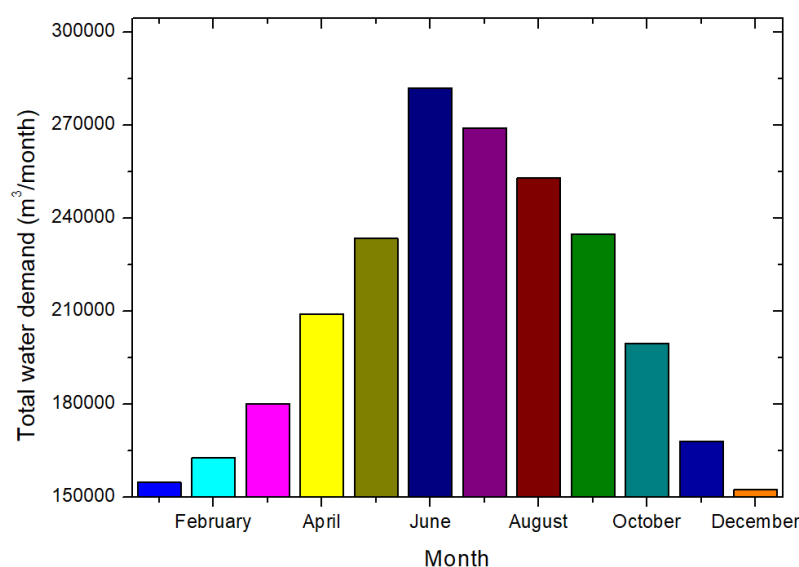
**Figure 18.** COMSOL simulated Chandler plant water demand amount in 24 h.

### 3.3.2. Monthly Irrigation Water Demand (2024)

June exhibited the highest irrigation demand (604.98 L/m<sup>2</sup>), totaling 275,000 m<sup>3</sup>, due to extreme heat and low humidity [76]. December had the lowest demand (326.70 L/m<sup>2</sup>) [77]—see Table 7 and Figure 19.

**Table 7.** COMSOL simulated water loss in 12 months of 2024 in Chandler, AZ.

| Month     | Average Temperature (K) | Wind Speed (m/s) | Humidity (%) | Water Loss (L/(m <sup>2</sup> ·Month)) |
|-----------|-------------------------|------------------|--------------|----------------------------------------|
| January   | 292.59                  | 3.58             | 46           | 331.85336                              |
| February  | 294.26                  | 4.47             | 42           | 348.61079                              |
| March     | 298.71                  | 4.92             | 34           | 386.50444                              |
| April     | 302.59                  | 5.81             | 23           | 448.69802                              |
| May       | 306.48                  | 5.81             | 19           | 500.90450                              |
| June      | 313.15                  | 5.81             | 17           | 604.97781                              |
| July      | 313.7                   | 6.26             | 29           | 577.2008                               |
| August    | 313.15                  | 5.81             | 33           | 542.56898                              |
| September | 310.37                  | 5.36             | 31           | 503.89951                              |
| October   | 304.26                  | 4.47             | 30           | 428.16043                              |
| November  | 297.04                  | 3.58             | 36           | 360.03574                              |
| December  | 291.48                  | 3.58             | 48           | 326.70268                              |

**Figure 19.** COMSOL simulated Chandler plant water demand by month in 2024.

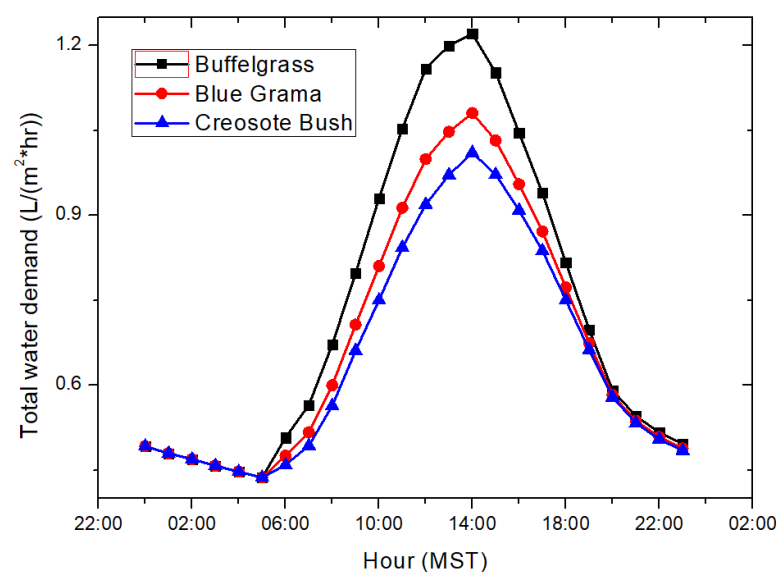
### 3.3.3. Arizona Vegetation Water Consumption Comparison

As a desert area with high temperature and low humidity, Chandler has its unique plants that are well-adapted to the hot and arid climate. Chosen from the University of Arizona's Desert Repository, Bermudagrass, Tall Fescue, Blue Grama and Buffelgrass are four of the most common grasses in Chandler. Some typical bushes in Chandler area include Creosote Bush, Red Yucca, and Oleander. Creosote, Bur-sage, and Brittlebush make up much of the native desert scrub community around Chandler. There are also some grasses in the town's desert landscape in both natural and disturbed areas. Blue Grama and **Purple Grama** are native Bunchgrasses that provide ground cover and soil stabilization. Non-native species like **Lehmann Lovegrass** have become increasingly dominant in disturbed soils and roadside areas. This grass was introduced for erosion control but is controversial because it can spread aggressively and outcompete native species. There are also some drought-tolerant trees such as Palo Verde, Mesquite, and Arizona Ash. In built environments around Chandler, plants from other arid regions have also become dominant. **Texas Sage**, with its silvery leaves and purple blooms, is a favorite for landscaping and thrives on little water. **Acacias** and thorny shrubs such as **Catclaw** and **Whitethorn**

are also common. Although not as iconic as Creosote or Brittlebush, these species shape much of the city's image, blending native Sonoran Desert vegetation with water-conserving landscape plants [78,79].

To further understand the impact of plant type on water demand, three typical plants were selected and simulated using COMSOL Multiphysics: a native grass—Blue Grama, an invading grass—Buffelgrass, and a bush—Creosote Bush. Blue Grama is native and highly drought-tolerant and requires much less water [80]. Buffelgrass is a non-native grass from Africa that was introduced for livestock forage and erosion control. It is highly invasive and creates a dense mat of flammable material [81]. Creosote Bush is an iconic desert shrub known for its very low water use and distinctive smell after rain. It has tiny, resin-coated leaves that minimize water loss [82].

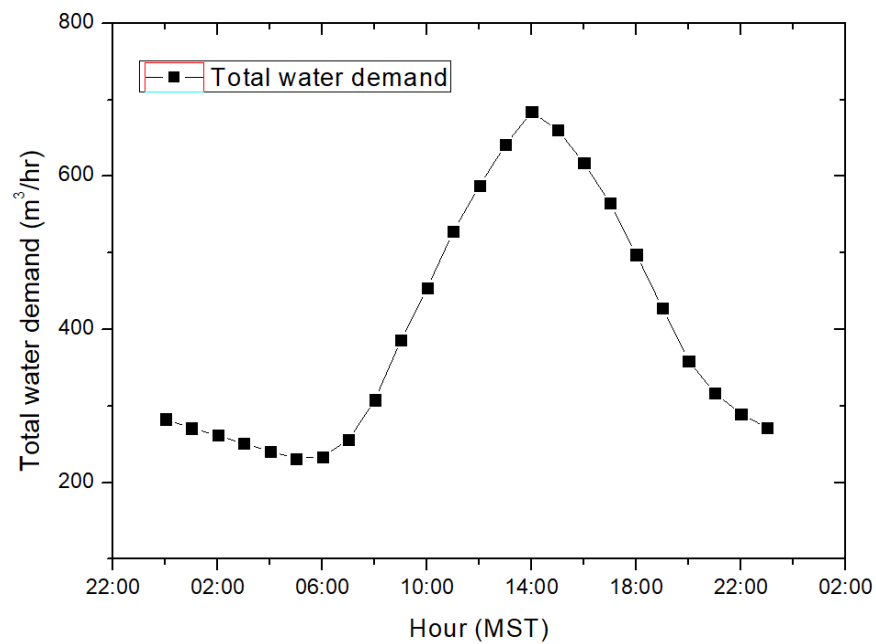
The COMSOL simulation results are summarized in Figure 20. As an invasive, fast-growing grass, Buffelgrass has a high leaf area index (LAI) and lacks the water-saving adaptations of native grasses. This explains its highest water demand in the graph. Blue Grama has a lower leaf area and can become dormant during long dry spells. This conservative water use allows it to survive in the arid climate of Chandler without constant irrigation. Compared with Buffelgrass, this native grass has a moderate water demand [83]. Among all three selected plants, Creosote Bush shows the lowest water demand. This plant is an extreme example of water conservation. Its deep roots and unique leaf structure allow it to thrive on minimal water [84].



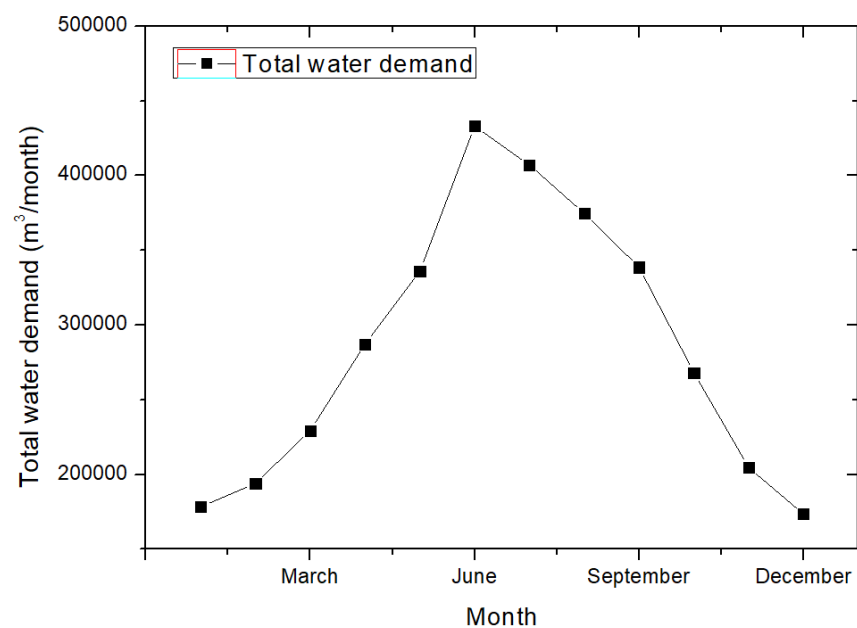
**Figure 20.** COMSOL simulated Chandler plant water demand by hour on 16 July 2024.

### 3.4. Total Water Demand

Combining evaporation and irrigation demands, June 2024 had the highest total water demand (425,000 m<sup>3</sup>), reflecting the combined impact of pool evaporation and vegetation irrigation [85]. Hourly variations peaked at 14:00, driven by high temperatures [86]—see Figures 21 and 22.



**Figure 21.** COMSOL simulated Chandler total water demand amount in 24 h.



**Figure 22.** COMSOL simulated Chandler total water demand amount by month in 2024.

### 3.5. Validation of Simulation Data by Real-Time Experiment Data

To validate the simulation data, a typical pool in Chandler was selected and the accurate hourly weather conditions (temperature, wind speed, and humidity) for two consecutive days were recorded (Table 8). The pool dimension is 4 m × 8 m × 2 m (L × W × H). Both days showed a 1 cm daily water level decrease, equivalent to 0.09 mL/s/m². The results match the simulation data in Figure 12 well [87]. This validated the COMSOL Multiphysics models used in the above simulation. More accurate water loss data can be achieved by running the simulation based on smaller time gaps between data points to obtain more frequent data [88].

Based on the simulation results, the water loss due to pool evaporation is equal to 3.7 times of the plant water demand. While specific statistics for Chandler, Arizona are unavailable, a common average size for a residential swimming pool is around 12 × 24 feet or

15 × 30 feet, with depths generally ranging from 3.5 to 5 feet. Under the assumption that the average pool size is 300 square feet, the simulations show that the water loss for such a pool is equivalent to the water requirements of an area of 1110 square feet planted with the three plants discussed in Section 3.3.3 (we used their averaged water consumption—see Figure 20). This is one of the main reasons that Chandler government encourages residents to use public community pools instead of building new private pools.

**Table 8.** Experimental data for two consecutive days in Chandler.

| Date      | Time (MST) | Temperature (K) | Wind Speed (m/s) | Humidity (%) | Date      | Time (MST) | Temperature (K) | Wind Speed (m/s) | Humidity (%) |
|-----------|------------|-----------------|------------------|--------------|-----------|------------|-----------------|------------------|--------------|
| 16/6/2025 | 12:00 AM   | 303.7           | 0                | 16           | 17/6/2025 | 12:00 AM   | 303.7           | 3.1              | 14           |
| 16/6/2025 | 1:00 AM    | 302             | 2.2              | 16           | 17/6/2025 | 1:00 AM    | 302             | 2.2              | 13           |
| 16/6/2025 | 2:00 AM    | 299.8           | 2.2              | 23           | 17/6/2025 | 2:00 AM    | 300.9           | 1.3              | 14           |
| 16/6/2025 | 3:00 AM    | 299.3           | 2.2              | 21           | 17/6/2025 | 3:00 AM    | 299.3           | 0.9              | 15           |
| 16/6/2025 | 4:00 AM    | 298.7           | 2.2              | 20           | 17/6/2025 | 4:00 AM    | 298.7           | 0.9              | 17           |
| 16/6/2025 | 5:00 AM    | 297             | 2.2              | 25           | 17/6/2025 | 5:00 AM    | 298.7           | 0.9              | 18           |
| 16/6/2025 | 6:00 AM    | 298.7           | 2.2              | 26           | 17/6/2025 | 6:00 AM    | 299.8           | 1.3              | 17           |
| 16/6/2025 | 7:00 AM    | 302             | 1.3              | 25           | 17/6/2025 | 7:00 AM    | 302.6           | 1.8              | 15           |
| 16/6/2025 | 8:00 AM    | 306.9           | 0                | 12           | 17/6/2025 | 8:00 AM    | 305.4           | 2.2              | 13           |
| 16/6/2025 | 9:00 AM    | 309.7           | 1.3              | 10           | 17/6/2025 | 9:00 AM    | 308.2           | 2.2              | 11           |
| 16/6/2025 | 10:00 AM   | 311.5           | 0                | 9            | 17/6/2025 | 10:00 AM   | 310.4           | 2.7              | 10           |
| 16/6/2025 | 11:00 AM   | 315.9           | 3.1              | 10           | 17/6/2025 | 11:00 AM   | 312.6           | 3.6              | 9            |
| 16/6/2025 | 12:00 PM   | 314.8           | 3.6              | 8            | 17/6/2025 | 12:00 PM   | 313.7           | 3.6              | 8            |
| 16/6/2025 | 1:00 PM    | 317.6           | 3.6              | 6            | 17/6/2025 | 1:00 PM    | 315.4           | 4                | 7            |
| 16/6/2025 | 2:00 PM    | 318.2           | 4                | 6            | 17/6/2025 | 2:00 PM    | 316.5           | 4.9              | 6            |
| 16/6/2025 | 3:00 PM    | 318.2           | 4.5              | 6            | 17/6/2025 | 3:00 PM    | 317             | 5.8              | 6            |
| 16/6/2025 | 4:00 PM    | 317             | 5.8              | 6            | 17/6/2025 | 4:00 PM    | 317.6           | 6.3              | 6            |
| 16/6/2025 | 5:00 PM    | 317             | 5.8              | 6            | 17/6/2025 | 5:00 PM    | 317             | 7.2              | 6            |
| 16/6/2025 | 6:00 PM    | 315.9           | 3.6              | 6            | 17/6/2025 | 6:00 PM    | 315.9           | 6.7              | 6            |
| 16/6/2025 | 7:00 PM    | 314.2           | 3.6              | 7            | 17/6/2025 | 7:00 PM    | 314.2           | 5.8              | 7            |
| 16/6/2025 | 8:00 PM    | 313.1           | 2.7              | 9            | 17/6/2025 | 8:00 PM    | 313.1           | 5.4              | 8            |
| 16/6/2025 | 9:00 PM    | 310.4           | 2.7              | 9            | 17/6/2025 | 9:00 PM    | 310.4           | 5.4              | 9            |
| 16/6/2025 | 10:00 PM   | 308.7           | 2.2              | 12           | 17/6/2025 | 10:00 PM   | 308.7           | 4.9              | 10           |
| 16/6/2025 | 11:00 PM   | 307.6           | 1.3              | 10           | 17/6/2025 | 11:00 PM   | 307.6           | 4.9              | 11           |

## 4. Water Conservation Strategies

### 4.1. Pool Water Conservation

FEA simulations suggest multiple strategies to reduce pool evaporation, which accounts for 61% of water surface loss in Chandler [89].

#### 4.1.1. Solar Covers

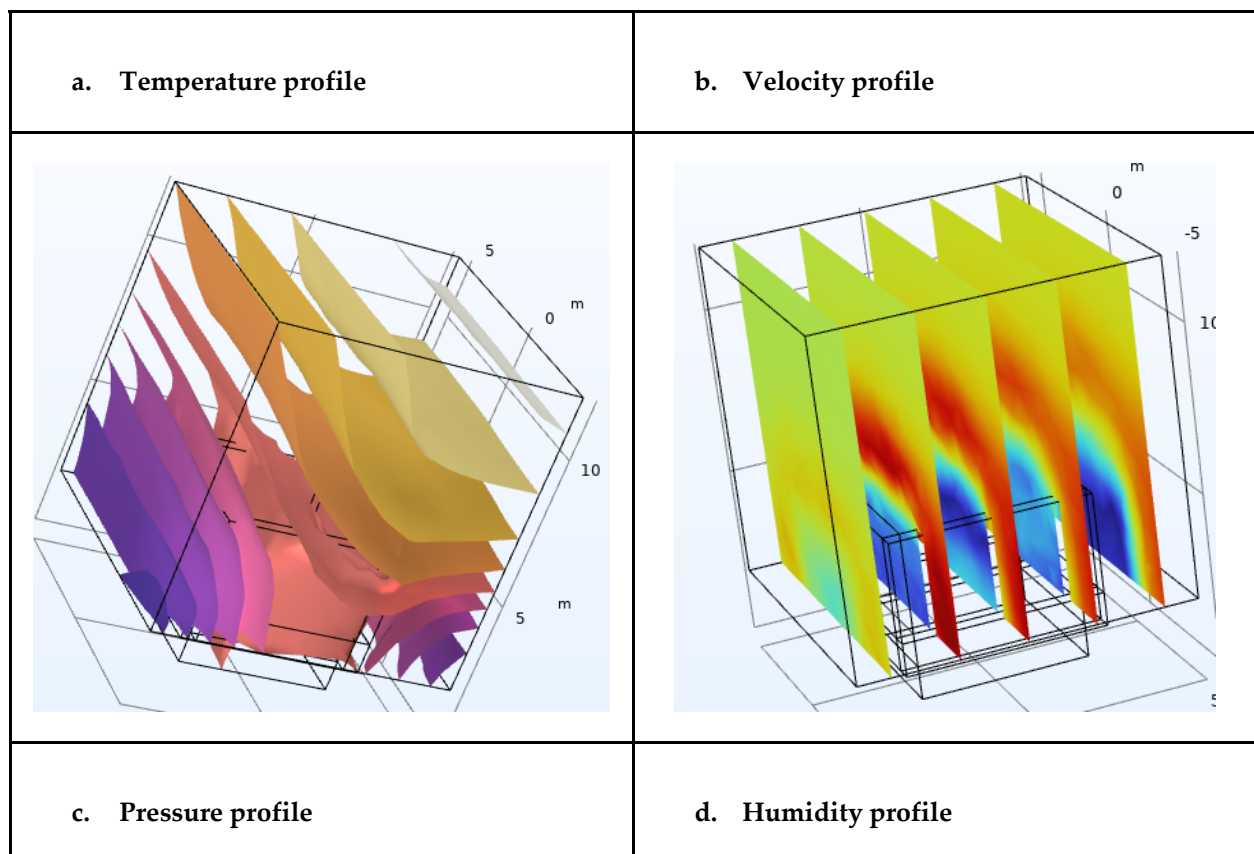
Since pool water loss accounts for over 60% water surface area in Chandler. One solution is to cover the pool with solar panels. Solar panels contribute to reducing pool temperatures by absorbing and converting solar radiation into electricity, thereby decreasing the amount of heat transferred to the pool surface. The panels act as a physical barrier, shading the pool and reducing direct exposure to sunlight, while also facilitating heat dissipation through convection and radiative cooling. Studies indicate that solar panels can lower pool surface temperatures by approximately 5–10 °C (9–18 °F) compared to unshaded conventional pools, depending on factors such as panel efficiency, installation height, and ambient conditions. From the simulation data, even a 1-degree temperature

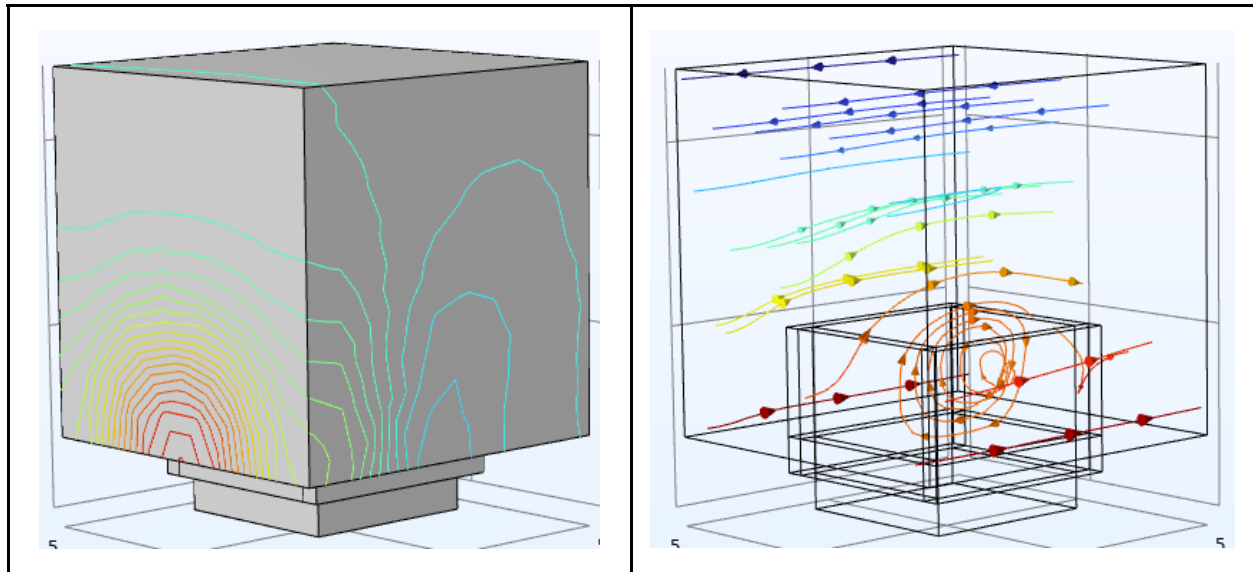
decrease can cause 10% less water evaporation loss [90]. Solar panels also generate electricity, enhancing sustainability [91].

#### 4.1.2. Fences

The second solution is to install a fence around the pool. This helps reduce the wind speed close to the pool water surface [92]. From the above simulation data, the lower wind speed significantly slows down the water evaporation loss rate [93]. To further understand the fence's impact on water loss. A 3D model of a pool with a fence was built in COMSOL. The pool–air–fence system was simulated. Figure 23a is the temperature profile. It is observed that the lower level (pool–air interface) has a lower temperature than the upper level. This proves that fences can help cool down the pool temperature and help reduce water evaporation. Figure 23b shows the wind velocity profile. The blue area (close to the pool–air interface) has significantly lower wind velocity. This also helps reduce the water loss rate due to evaporation. Figure 23c shows the pressure profile around the fenced pool. The lines represent the intensity of pressure, water pressure increases in proportion to how much the fence covers the water.

The fence can also help isolate the local environment between the pool water surface and the air above. This increases the relative humidity in the boundary layer of air and pool water surface [94]. With the increase in humidity, the water evaporation loss rate decreases [59]. Figure 23d shows the humidity profile data. The fence caused a nonuniform humidity distribution. The top of the air (blue arrows) has the lowest humidity. When it is approaching the fence, there is a significantly increased concentration of water species. This leads to higher relative humidity. The water evaporation rate is suppressed by higher humidity. The simulation proves that the fence can help reduce the pool–air interface temperature, decrease the wind speed, and increase the relative humidity. All these impacts help mitigate water loss due to evaporation.





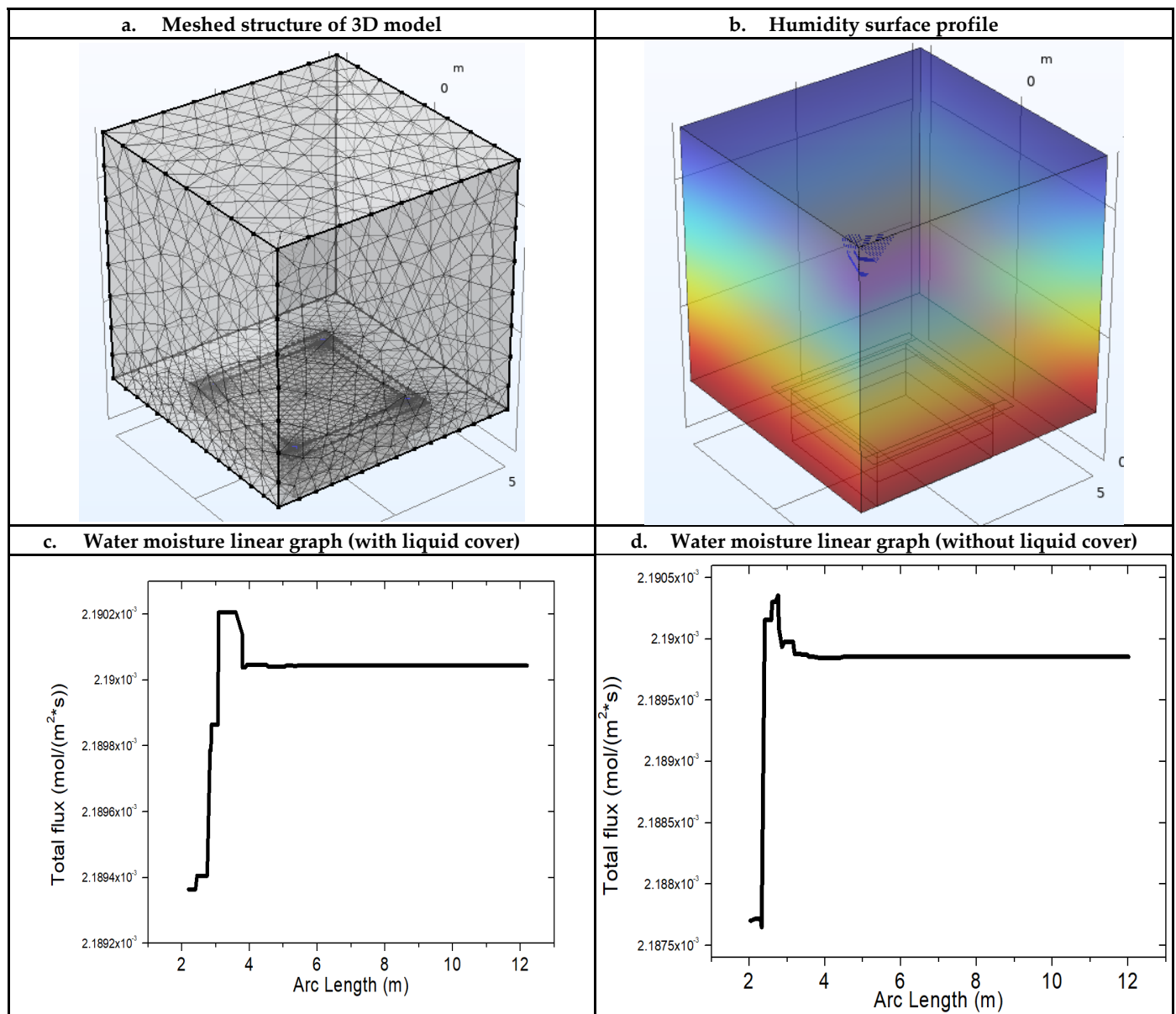
**Figure 23.** COMSOL simulation of fence impact on pool water evaporation, (a) Temperature profile; (b) Velocity profile; (c) Pressure Profile; (d) Humidity Profile

#### 4.1.3. Liquid Solar Cover on the Water Surface

Liquid solar covers reduce water evaporation by forming a monomolecular layer on the pool's surface. This ultra-thin film acts as a physical barrier that significantly lowers the water's surface tension. This phenomenon works by reducing the energy required for water molecules to escape into the air as vapor. This mechanism is distinct from physical covers, as the liquid layer continuously reforms even with minor surface disturbances from wind or swimming.

The primary benefit of using a liquid cover is its low cost and adaptability in environments. Furthermore, reducing evaporation cuts down evaporation rates from the pool. Since evaporative cooling is the dominant form of heat dissipation, maintaining a stable liquid layer helps retain the water's temperature, potentially extending the swimming season and decreasing energy consumption for heated pools. This also leads to secondary benefits, such as the slower dissipation of pool chemicals, as they remain concentrated longer in the water.

To validate the impact of liquid cover, the COMSOL 3D model was updated to add thin liquid layer. The simulation data show clear differences at the water–air interface. The meshed structure shows that the simulation utilizes finer discretization around the pool, ensuring accuracy (Figure 24a). The Humidity profile reveals that there is a higher moisture content near the pool (Figure 24b). For the model with a thin liquid layer, the water moisture concentration increases slowly with step size (Figure 24c). For the model without liquid cover (Figure 24d), the water moisture concentration immediately increases to a maximum. All this proves that the thin liquid cover can help reduce water evaporation and preserve water inside the pool.



**Figure 24.** COMSOL simulation of liquid cover impact on pool water evaporation. (a) Meshed structure of 3D model; (b) Humidity Surface Profile; (c) Water moisture with liquid cover; (d) Water moisture without liquid cover

#### 4.2. Irrigation Optimization

To save irrigation water, there are several things to consider. The first thing is how much water is required for sustaining a plant. The second thing is how much water is lost due to water evaporation from the soil. The third thing is the irrigation time and frequency. If irrigation is set to turn on during the hottest time, such as around 2 pm, more water is lost due to the high evaporation loss rate. All these parameters need to be optimized to maximize the water savings.

##### 4.2.1. Minimum Water Requirements

The minimum water amount was calculated by adding the soil water evaporation loss to the plant uptake water amount. This is the minimum water the plant needs for life sustenance. From the above simulation, this minimum water amount varies with time and is very sensitive to temperature, wind speed, and humidity around the plant [95]. Current irrigation systems often apply water uniformly, leading to waste [96]. Simulations

quantified minimum requirements to sustain grass, ensuring soil moisture remains above the wilting point [97].

#### 4.2.2. Dynamic Irrigation on/off Timing

An optimal irrigation system should be able to have dynamic power management, irrigation length, and irrigation frequency. The smart system would capture the real-time environment and weather conditions using sensors or use data from a real-time database. Based on the collected data, it can calculate the minimum water demand and only maintain the minimum irrigation time. Dynamic irrigation systems, using real-time environmental data from sensors or databases, can adjust watering schedules to minimize waste [98]. Avoiding irrigation at 14:00, when evaporation peaks, enhances efficiency [99].

#### 4.2.3. Optimal Irrigation Duration

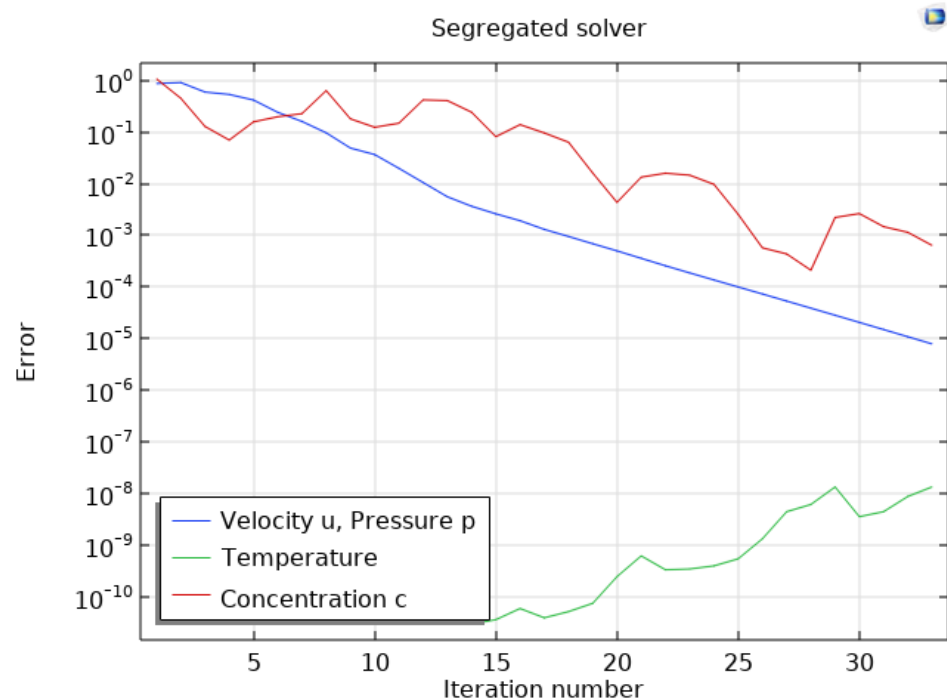
It is paramount to pick optimal irrigation timing to avoid unnecessary water loss during peak temperatures, such as 2 pm, when temperatures are the highest, which can result in significant water loss due to elevated evaporation rates. But if the irrigation was turned on at 5 am, the coolest period during the day, water retention in plants would be much higher [100]. To maximize irrigation efficiency, a more complex model needs to be developed to simulate the time-dependent change in the water demand and water evaporation loss during the day. Such an irrigation model can be built and integrated into the control systems to minimize water usage. Advanced models integrating time-dependent water demand can optimize schedules [101].

#### 4.2.4. Dynamic Irrigation Frequency

Current standard irrigation settings (e.g., every 6 h for 10 min) cause significant waste [102]. Dynamic systems that adjust frequency and duration based on real-time conditions can reduce water use [103].

### 4.3. Simulation Convergence Analysis

Figure 25 shows the convergence plot generated by COMSOL during the simulation. The relative tolerance is set as 0.001. Under tight tolerance settings, all parameters (velocity, pressure, temperature and concentration) can converge well during the simulation. This well-converged simulation provides confidence that the numerical solution is robust, has reached a stable state, and is a reliable approximation of the true physical behavior being modeled, given the specified model setup and discretization.



**Figure 25.** Convergence plot for the COMSOL simulation of 3D model.

## 5. Discussion

The simulations successfully demonstrate the daily and annual water demands for pools and vegetation in the typical Arizona city of Chandler and uses COMSOL's Multiphysics capabilities. The current study investigates the usage across several main categories to provide a comprehensive understanding of water loss rate and mechanism. The simulation information can be used to accurately scale the water demands, which is crucial for regional planning in the water-poor state of Arizona. The results should help the government better predict the future water demand and develop policies for water conservation strategies. Since the pools drive over 60% of water loss due to surface water evaporation, the government could encourage community pools while reducing the number of private pools. This should reduce the total water surface area and significantly reduce the water loss due to evaporation.

But of course, there are limitations as well. For seasonal variability, the annual estimates are based on seasonal factors; we need good local data. In summertime, the temperature changes from day to night are huge. The wind speed is also variable. This would likely produce corresponding variation in water demand [104,105]. For the irrigation simulation, a simple plant uptake model leads to smaller water demand. More accurate models will likely be used in future irrigation studies [106]. Real-time satellite data can be integrated [107,108] as well.

Our simulations showed that installing fences can effectively reduce water loss from evaporation by lowering wind speed, which raises humidity near the surface and decreases the moisture gradient (which in turn drives the evaporation). A logical takeaway is that evaporation would also decrease when pools are built with deeper water surfaces.

## 6. Conclusions

In this work, the applicability of COMSOL Multiphysics for the calculation of water demands for pools and for vegetation in Chandler, Arizona is shown. Temperature, humidity, and wind speed were modeled, and daily and annual water losses were calculated; June 2024 simulations required 425,000 m<sup>3</sup>. The research provided the first

systematic investigation of the usage within the defined categories. Pools cause 61% of the surface water evaporation in the area and, therefore, should have special conservation measures.

The model was validated with experimental results. Based on the simulation, different solutions were proposed to reduce the water consumption and minimize the water loss. Some active measures include the optimization of irrigation time and frequency based on dynamic and real-time environmental conditions. The proposed solution can help minimize the water consumption while maintaining the water demands for plant life sustenance. Other passive measures include the modification of localized environmental conditions to reduce water evaporation. It was found that installation of fences can significantly change the water vapor flow and distribution close to the water surface and suppress the water evaporation. Similarly, evaporation would also decrease when pools are built with deeper water surfaces.

The research provides a more accurate solution for the government to better predict future water usage and develop policies for more efficient water conservation strategies. This work used simplified plant models to focus on the understanding of water loss mechanism due to environment conditions.

## 7. Future Work

Future work could extend our simulations with more accurate plant models and information to understand the plant type impact and help the water balance of territories with few inhabitants [81]. While only three plants were simulated to measure the general water consumption for Arizona vegetation consumption, future work is dedicated for more specific parameters from these organisms. Another possible parameter is to take into account soil composition and porosity when simulating water consumption. Because Arizona has a multitude of terrains from silt to sand, simulations could be performed with these materials as the ground layer.

In this paper, we analyzed/modeled evapotranspiration from three plants—a native grass—Blue Grama, an invading grass—Buffelgrass, and a bush—Creosote Bush. In a follow-up paper, we plan to expand this analysis and model evapotranspiration for numerous plants that are typical around Chandler, Arizona and that we discussed in sub-Section 3.3.3 Arizona vegetation water consumption comparison.

An important extension would also be to consider the effects of global warming and climate change on evaporation and evapotranspiration. In order to fully understand how evaporation and evapotranspiration impact the world from a local level, further analysis must be performed to mitigate water loss from these causes.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/w17192835/s1>.

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