Department of Civil & Architectural Engineering

SUREAL - Built Environment Team in Collaboration with EXP as Industry Partners Presents

Water Conservation Analysis

Residential water consumption modeling and water conservation measure analysis

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Executive Summary: Water Conservation and Codes: Leveraging Global Water-Efficient Building Standards to Avert Shortfalls

Nearly two-thirds of the world's population experience severe water scarcity for at least one month each year, and some 700 million people could be displaced by intense water scarcity by 2030. Over the next 50 years, nearly half the U.S.'s freshwater basins may not be able to meet the monthly water demand with anticipated shortages beyond the Southwest, including in the central and southern Great Plains, central Rocky Mountain states, as well as parts of California, the South, and the Midwest. Facing these challenges, solutions at all levels of government are critical.

Although, to date, many water conservation efforts have focused on utility-scale solutions, including reclamation, desalination, and storage projects, decentralized efforts at the individual building scale can, in the aggregate, be equally as impactful.

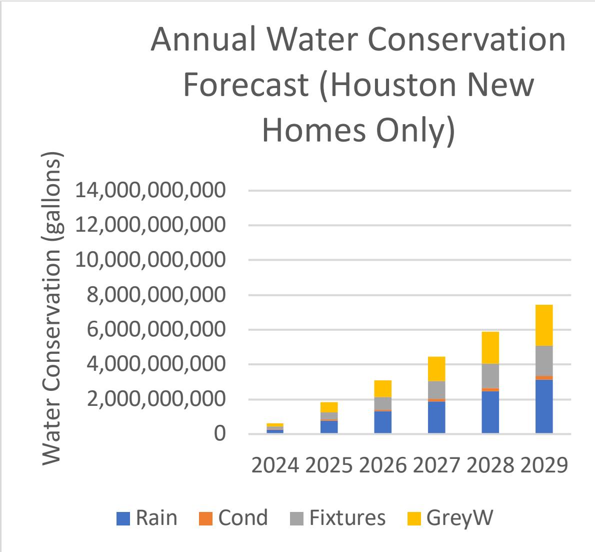
To quantify this opportunity, the Code Council, which develops and publishes a set of codes and standards that play a crucial role in shaping construction practices, partnered with the University of Miami to release **"Water Conservation and Codes: Leveraging Global Water-Efficient Building Standards to Avert Shortfalls."** This report, produced by the University of Miami, examines the critical need for the rapid adoption of the updated water conservation standards contained in the 2021 International Water Conservation Code Provisions (IWCCP).

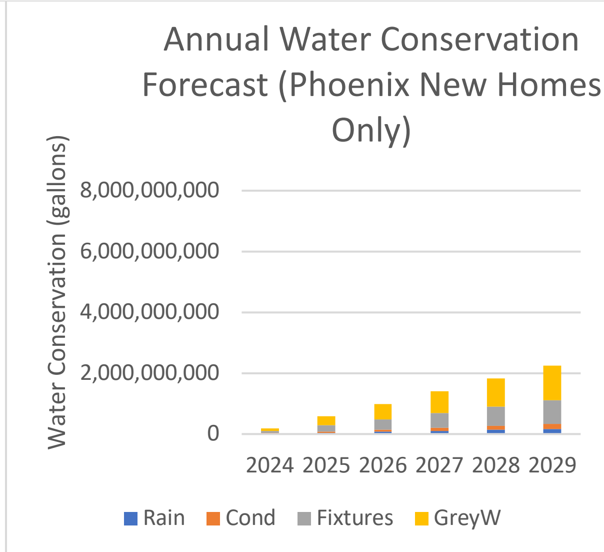
After determining baseline potable and non-potable water use, the Study shows potential water savings for one-and two-family dwellings in Phoenix, Las Vegas, Houston and Des Moines based on adoption of four different water conservation strategies within the IWCCP:

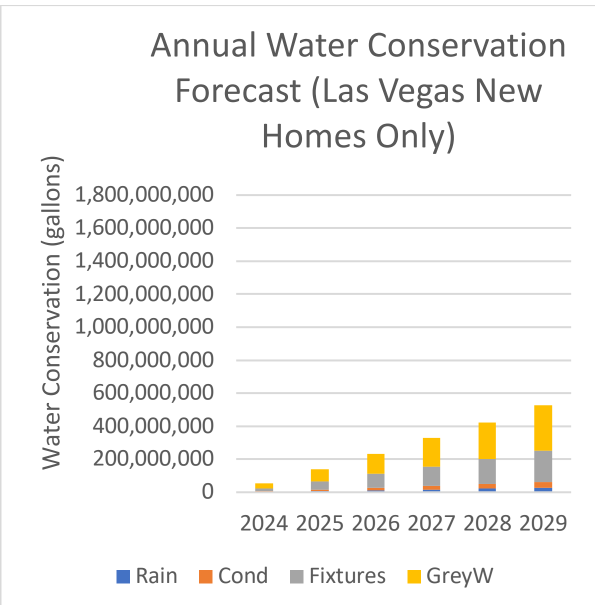
- Adoption of more efficient plumbing fixtures;
- Rainwater harvesting, treatment, storage, and reuse;
- Grey water treatment, storage, and reuse; and
- HVAC condensate catchment, treatment, storage, and reuse.

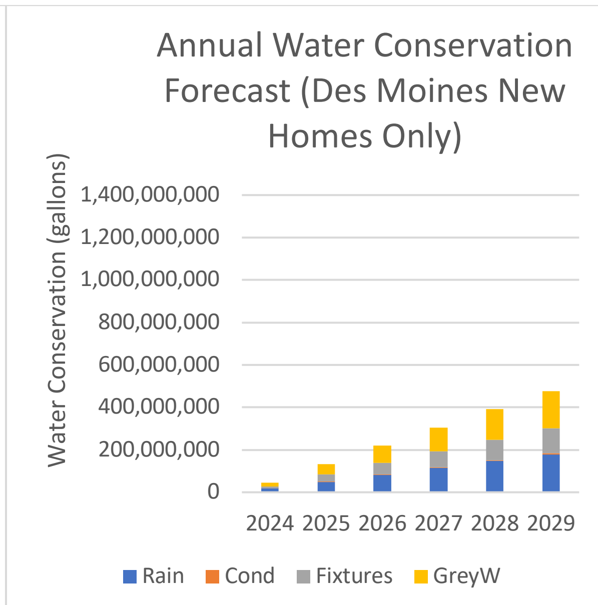
Recognizing that some but not all these strategies may be additive and that some may be more optimal for different climate zones and geographies than others, the report also includes recommended combined approaches for the 4 areas studied.

Over six years, the total annual potential aggregate water conservation for new construction homes in Houston, Texas alone is 23.34 billion gallons. In Phoenix, Arizona it's 7.3 billion gallons. For all four markets included in the study, including Des Moines, Iowa (1.7 billion) and Las Vegas, Nevada (1.7 billion) respectively, the aggregate water conservation is more than 34 billion gallons of water for American families in four major cities. This is an astonishing finding, confined to new construction homes. Even more notable, in each of the four cities studied, conservation measures can be utilized at a cost per gallon that equates with the current per gallon cost of potable water.









The measures studied provide solutions to address meaningful water demand challenges in these regions. Over the next 50 years, Houston faces a 72-billion-gallon shortfall, Arizona has limited new housing construction in the Phoenix area that depends on groundwater, and the Las Vegas Valley Water District sees a high risk of ongoing shortage conditions in future years while Des Moines Water Works says that if drought conditions – now in their fourth year – continue, water shortage measures will be required.

Ultimately, the report demonstrates the enormous potential that building-level approaches offer and provides policymakers with a ready-made toolkit to integrate lasting water conservation measures in communities in the U.S. and beyond.

Contents

1.0 Introduction

Global water use has surged over the past century, driven by a combination of factors including population growth, economic development, and changing habits**.** This has led to a situation where many regions already struggle with water scarcity, and the situation is expected to worsen in the coming decades as a result of climate change impacts. Water demand is expected to rise significantly in all sectors, including industry, domestic use, and agriculture. Water scarcity is a growing problem for many countries, and is likely to affect many more by 2050 (Boretti, A., Rosa, L. 2019; United Nations World Water Development Report).

Rapid urbanization and rising water use, which put stress on centralized systems, provide significant difficulties for urban water infrastructure. Historically, cities have relied on these systems, but they are unable to meet the growing needs and are made worse by problems including resource-intensive operations, outdated infrastructure, and inefficient energy use. Consequently, it is clear that moving toward decentralized methods is urgent. (Kalbar & Lokhande, 2023).

A comprehensive approach that prioritizes resilience and sustainability in urban water management is provided by decentralization. This paradigm change makes use of technical developments in recycling, water treatment, and monitoring to build more flexible and effective systems (Yuankai Huang, 2023). Decentralized water infrastructure adoption is also greatly aided by favorable legislation and greater community involvement.

A primary benefit of decentralized systems is their scalability, which facilitates customized solutions to be executed at different levels to satisfy certain requirements. With this flexibility, towns may strike a balance between things like life-cycle costs, simplicity of governance, resistance to extreme events, and the advantages of recycling water. Developed and developing countries alike can tackle urgent water issues and create more robust and sustainable water systems for the future by deploying decentralized urban water infrastructure strategically. This strategy improves the general quality of life for urban dwellers while simultaneously easing the burden on centralized services and encouraging environmental conservation.

Internationally, code officials and designers recognize the need for a modern, up-to-date code governing the impact of buildings and structures on the environment. The *International Water Conservation Code Provisions* (IWCCP) of 2021, which includes provisions from the *International Green Construction Code* (IgCC), co-developed by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), USGBC (U.S. Green Building Council), and IES (Illuminating Engineering Society), as well as provisions from the *National Green Building Standard* (ICC 700) provide meaningful help to address these needs. The IWCCP is designed to meet this need through model code regulations that contain clear and specific requirements with provisions that promote water conservation through safe and sustainable construction in an integrated fashion with the ICC Family of Codes. Demonstration of potential benefits of these code provisions is essential for policymakers to recognize their benefits and adopt them as minimum requirements in the regulatory arena rather than continuing to recommend their use in voluntary compliance programs under a variety of nonregulatory settings.

The SUREAL Engineering Lab strives to create innovative, next-generation concepts and designs to help at-risk communities combat stressors due to climate change. Our team consists of University of Miami (UM) Faculty, Architectural and Civil Engineering PhD and Construction Management students. Our Team in collaboration with a team of Professional Engineers from EXP U.S. Services Inc. (EXP) with extensive background in building codes, building guidelines, standards, design, construction management and green engineering has undertaken a comprehensive pilot investigation aimed at demonstrating potential benefits of the noted code provisions to enhance water conservation practices across four strategic cities. Leveraging our collective expertise and resources, we are committed to optimizing water usage and fostering sustainability in urban environments through meticulous and strategically applied analysis.

Our collective team brings over 40 years of unparalleled experience in engineering, architecture, design, and applied research to the forefront. EXP's multidisciplinary team, organized into six key practice areas—Buildings, Earth & Environment, Energy, Industrial, Infrastructure, and Sustainability—has a proven track record of delivering innovative solutions on a global scale. UM, a prestigious institution renowned for its excellence in research and academia and EXP partnership in this project, underscores our collective commitment to excellence and forward-thinking.

Our initiative centers on a comprehensive examination of water conservation measures and associated costs in Houston, Texas; Phoenix, Arizona; Las Vegas, Nevada; and Des Moines, Iowa. This analysis entails a meticulous comparison between the currently adopted plumbing codes and the IWCCP across these four cities. By selecting locations from diverse geographical regions with varying climatic conditions, our aim is to highlight opportunities for optimizing and aligning sustainable practices through a detailed and itemized analysis.

To achieve this objective, our methodology incorporates rigorous modeling analysis, evaluating the effectiveness of current code standards against proposed green code implementations. This includes an exhaustive examination of site and building water use efficiencies, domestic water distribution systems, plumbing fixtures and features, as well as measurement and treatment methods. Information and analysis are presented in written and/or itemized table format, covering all topics related to domestic water conservation.

Furthermore, our approach extends beyond theoretical analysis to practical implementation. We conduct regional comparison studies for both single-family and multi-family residential structures, considering factors such as square footage, fixture types, quantities, and viable conservation strategies. This enables us to provide tailored recommendations specific to the unique characteristics of each city, ensuring actionable insights for stakeholders.

Phase I (water conservation) of our initiative lays the groundwork for subsequent phases by establishing a robust framework for data collection, analysis, and interpretation. All findings and methodologies are meticulously documented to ensure transparency, reproducibility, and scalability for future endeavors. The investigation approach and findings from this study are detailed in the sections below, beginning with the current state of relevant codes in use, establishment of baseline model for water consumption, and potential water conservation measures for the four cities selected. The water conservation measures considered are categorized into supplemental water sources and water use efficiency as further detailed in sections 4 and 6 of this report.

In sum, our recommendations are the result of a collaborative effort to address the critical challenges of water conservation in urban environments through research-driven analysis and practical solutions. We are confident that our approach will yield tangible benefits, setting a new standard for sustainable development and water management practices.

2.0 State of Code Review

The International Plumbing Code (IPC) serves as the fundamental framework for ensuring the sustainability, efficiency, and safety of plumbing and building systems. This code, while adopted in various forms by different cities, undergoes localized modifications to cater to specific regional needs. Some jurisdictions utilize the Uniform Plumbing Code (UPC) in place of the IPC, which this report also considers.

The selection of four major cities in the United States—Houston, Phoenix, Las Vegas, and the Des Moines area—exemplifies the diversity of construction and plumbing regulations nationwide, reflecting distinct climatic and geographic conditions. These examples serve as valuable insights into how regional requirements shape legal frameworks.

Chosen for their unique topography and climate, each city's selection underscores the profound influence of environmental factors on construction and plumbing codes. This comparison not only highlights the ongoing evolution of codes in response to emerging challenges and advancements but also sheds light on the diverse regulatory landscapes across the nation.

Of particular significance is the introduction of the 2021 International Water Conservation Code Provisions (IWCCP), which holds promise for bolstering water conservation efforts and safeguarding public health and the environment. In many regions, this initiative signifies a significant stride towards embracing sustainable water management techniques.

In the United States, plumbing regulations follow different codes on a state-by-state or municipal basis. Most of the states/municipalities have adopted the IPC, while some have adopted the UPC, often with their own amendments.

While basic fixture flow rates and general conservation measures are covered in the aforementioned codes, regulations concerning more advanced water conservation practices are not their primary focus. The IWCCP, in conjunction with the aforementioned codes, seeks to enhance these existing baselines by establishing necessary requirements to safeguard both public health and environmental impacts. The following sections summarize the codes currently in use at each of the four cities under study, serving as a reference point for establishing baseline water consumption predictions.

2.1 Houston, Texas

2021 International Building Code (IBC) with Amendments
2021 International Residential Code (IRC) with Amendments
2021 Uniform Plumbing Code (UPC) with Amendments

2.2 Phoenix, Arizona

2018 International Building Code (IBC) with Amendments
2018 International Residential Code (IRC) with Amendments
2018 International Plumbing Code (IPC) with Amendments
2018 Uniform Plumbing Code (UPC) with Amendments

2.3 Las Vegas, Neveda

2021 International Building Code (IBC) with Amendments
2018 International Residential Code (IRC)
2018 Uniform Plumbing Code (UPC)

2.4 Des Moines, Iowa

2018 International Building Code (IBC) with Amendments
2018 International Residential Code (IRC) with Amendments
State Plumbing Code (Based on the 2021 Uniform Plumbing Code)

3.0 Baseline Water Consumptions per City

3.1 Single-Family Residential Home

Water consumption can be categorized as either potable or non-potable. Potable water is of a quality suitable for drinking, cooking, and personal bathing which meets the requirements of Public Health Service Drinking Water Standards or the regulations of the local public health Authority Having Jurisdiction. Non-potable water is not suitable for human consumption and as such is not treated to the required drinking water standards. Currently, uses of non-potable water vary significantly across different regions and regulatory frameworks and may be used for water closets, urinals, irrigation, and HVAC makeup water.

The tables below represent the estimated baseline consumption for a home in each of the four cities following the *code minimum* provisions for new residential construction in each respective city. Several assumptions were made to develop the baseline water consumption profile; please refer to the data below and included in the report appendices for additional information.

Figure I: Single-family residential home

The average single-family residential home being considered for each of the four cities is a 1,750 square foot two-story house with attached two-car garage yielding an approximate roof area 1,200 square feet and located on a 0.25-acre parcel of land yielding approximately 0.20 acres or 9,000 square feet for landscape irrigation. Typical lawn irrigation considered is 6 gpm for lawn sprinklers operating for 30 minutes per day, 3 days per week. The example home / parcel size in square foot / acres described above was defined as an average estimate in order to exemplify rainwater harvesting potential in each subject city and the associated results are distinguished from other conservation provisions as documented in the analysis section of this report.

While typical example home has been listed to be based on having 3 bedrooms and 2.5 bathrooms, the actual analysis has been carried out using occupant density per home rather than square foot area, number of bedrooms or number of bathrooms, based on published census data associated with each subject city as summarized below:

Houston, Texas : **2.52** people per home
Phoenix, Arizona : **2.68** people per home
Las Vegas, Nevada : **2.65** people per home
Des Moines, Iowa : **2.34** people per home

While multiple water conservation measures are addressed and offered by the 2021 International Water Conservation Code Provisions (IWCCP), this study focused on just four measures as described below, when analyzing and documenting benefits in the subject cities:

A. Use of water efficient fixtures;
B. Grey water harvesting for reuse;
C. Rainwater harvesting; and
D. Condensate harvesting from HVAC systems.

Although hot water systems and hot water distribution networks were identified as other important conservation provisions, given the potential in design and system type variations and need for more in depth data collection in order to produce reliable study outcomes, these measures were reserved to be coupled with energy conservation benefit investigation at a later phase of our study.

The sections below summarize the estimated daily water consumption based on the predefined home size and occupancy rates in each of the four subject cities. The occupancy rates have been averaged based on U.S. Census data; while the occupancy rates in single family detached homes may be higher, it has been our intent to conduct this study using lower occupancy rates as a more conservative approach. The total estimated consumption volumes are hypothesized into two supply stream categories, defined as potable and non-potable, in order to quantify the potential for water conservation benefits, when considering water reuse applications within existing regulatory framework guidelines.

3.1.1 Average Single-Family Residential Home – Houston, Texas

The average household size in the Houston, Texas area is 2.52 people per home (U.S. Census Bureau 2018-2022).

Houston Texas, Single-Family Home				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
3	Lavatory Faucet	X		16.6
2	Shower Head	X		63.0
1	Kitchen Sink Faucet	X		55.4
3	Water Closet	X	X	19.4
1	Clothes Washer	X		19.0
1	Dishwasher	X		4.2
2	Hose bibbs	X	X	15.0
	Irrigation only	X	X	77.1
			Total	269.8

Table 1:Baseline Household Water Consumption per Day for Single Family in Houston

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 158 gallons or 59% of the total daily consumption.
Total daily non-potable consumption is 111 gallons or 41% of the total daily consumption.

3.1.2 Average Single-Family Residential Home – Phoenix, Arizona

The average household size in the Phoenix, Arizona area is 2.68 people per home (U.S. Census Bureau 2018-2022).

Phoenix Arizona, Single-Family Home				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
3	Lavatory Faucet	X		17.7
2	Shower Head	X		67.0
1	Kitchen Sink Faucet	X		59.0
3	Water Closet	X	X	25.7
1	Clothes Washer	X		19.0
1	Dishwasher	X		4.2
2	Hose bibbs	X	X	15.0
	Irrigation only	X	X	77.1
			Total	284.7

Table 2: Baseline Household Water Consumption per Day for Single Family in Phoenix

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 167 gallons or 59% of the total daily consumption.
Total daily non-potable consumption is 118 gallons or 41% of the total daily consumption.

3.1.3 Average Single-Family Residential Home – Las Vegas, Nevada

The average household size in the Las Vegas, Nevada area is 2.65 people per home (U.S. Census Bureau 2018-2022).

Las Vegas Nevada, Single-Family Home				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
3	Lavatory Faucet	X		17.5
2	Shower Head	X		66.3
1	Kitchen Sink Faucet	X		58.3
3	Water Closet	X	X	25.4
1	Clothes Washer	X		19.0
1	Dishwasher	X		4.2
2	Hose bibbs	X	X	15.0
	Irrigation only	X	X	77.1
			Total	282.8

Table 3: Baseline Household Water Consumption per Day for Single Family in Las Vegas

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 165 gallons or 58% of the total daily consumption.
Total daily non-potable consumption is 118 gallons or 42% of the total daily consumption.

3.1.4 Average Single-Family Residential Home – Des Moines, Iowa

The average household size in the Des Moines, Iowa area is 2.34 people per home (U.S. Census Bureau 2018-2022).

Des Moines Iowa, Single-Family Home				
Baseline Household Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
3	Lavatory Faucet	X		15.4
2	Shower Head	X		58.5
1	Kitchen Sink Faucet	X		51.5
3	Water Closet	X	X	22.5
1	Clothes Washer	X		19.0
1	Dishwasher	X		4.2
2	Hose bibbs	X	X	15.0
	Irrigation only	X	X	77.1
			Total	263.2

Table 4: Baseline Household Water Consumption per Day for Single Family in Des Moines

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 149 gallons or 56% of the total daily consumption.
Total daily non-potable consumption is 115 gallons or 44% of the total daily consumption.

3.2 Multi-Family Residential Condominium/ Townhouse Building

Analysis was also carried out for multi-family low-rise residential buildings; the average multi-family residential building being considered for each of the four cities is a low-rise condominium/townhouse building of 3 or fewer stories with twelve (12) 1,500 square foot dwelling units totaling an approximate gross square footage of 20,000 square feet. The average approximate roof area of the building is 7,500 square feet. Roof area would be +/- 20% depending on whether the overall building height was 2 or 3 stories. A detached garage building with twelve (12) 250 square feet single car parking spaces totaling 3,000 square feet is also being considered. Both structures are assumed to be located on a 1.0-acre parcel of land yielding approximately 0.1 acres or 5,000 square feet for landscape irrigation.

The example multi-family residential building size described above was again defined as a conservative estimate based on published census data associated with each subject city, representing roughly 11% for Des Moines, 24% for Houston, 24% for Las Vegas and 15% for Phoenix % of the total residential housing stock in each city. While the home sizes and occupancy counts may vary, again as a conservative approach, 1,500 square foot dwelling unit size with 2.5 bathrooms and roughly 2.3 - 2.7 people per home was considered for the subject cities, when documenting potential for water conservation.

Similar to single family homes, this study also focused on just four measures as described below, when analyzing and documenting benefits in the subject cities:

A. Use of water efficient fixtures;
B. Grey water harvesting for reuse;
C. Rainwater harvesting; and
D. Condensate harvesting from HVAC systems.

As mentioned earlier, although hot water systems and hot water distribution networks were identified as other important conservation provisions, given the potential in design and system type variations for multi-family buildings and need for more in depth data collection in order to produce reliable study outcomes, these measures were reserved to be coupled with energy conservation benefit investigation at a later phase of our study, and not included in the results of this study.

The tables below represent the estimated baseline consumption for a multi-family residential building in each of the four cities following the *code minimum* provisions for new residential construction in each respective city. Several assumptions were again made to develop the baseline water consumption profile; please refer to the data below and included in the report appendices for additional information.

Figure II: Multi-family residential building

In order to quantify and demonstrate potential demand for non-potable water sources, and exemplify potential benefits from rainwater / grey water / condensate water harvesting provisions for water reuse, landscape irrigation was considered as 30 gpm for lawn sprinklers operating for 30 minutes per day, 3 days per week.

3.2.1 Average 12 Unit Multi-Family Residential Building – Houston, Texas

The average household size in the Houston, Texas area is 2.52 people per dwelling unit (U.S. Census Bureau 2018-2022).

Houston Texas, 12 Unit Multi-Family Residential Condominium/Townhouse Building				
Baseline Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
36	Lavatory Faucet	X		199.6
24	Shower Head	X		756.0
12	Sink Faucet	X		665.3
36	Water Closet	X	X	232.2
12	Clothes Washer	X		228.0
12	Dishwasher	X		50.4
24	Hose bibbs	X	X	N/A
	Irrigation only	X	X	385
			Total	2,516.5

Table 5: Baseline Household Water Consumption per Day for Multi-Family unit in Houston

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 1,899 gallons or 75% of the total daily consumption.
Total daily non-potable consumption is 617 gallons or 25% of the total daily consumption.

3.2.2 Average 12 Unit Multi-Family Residential Building – Phoenix, Arizona

The average household size in the Phoenix, Arizona area is 2.68 people per dwelling unit (U.S. Census Bureau 2018-2022).

Phoenix Arizona, 12 Unit Multi-Family Residential Condominium/Townhouse Building				
Baseline Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
36	Lavatory Faucet	X		212.3
24	Shower Head	X		804.0
12	Sink Faucet	X		707.5
36	Water Closet	X	X	308.7
12	Clothes Washer	X		228.0
12	Dishwasher	X		50.4
24	Hose bibbs	X	X	N/A
	Irrigation only	X	X	385
			Total	2,695.9

Table 6: Baseline Household Water Consumption per Day for Multi-Family unit in Phoenix

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 2,002 gallons or 74% of the total daily consumption.
Total daily non-potable consumption is 694 gallons or 26% of the total daily consumption.

3.3.3 Average 12 Unit Multi-Family Residential Building – Las Vegas, Nevada

The average household size in the Las Vegas, Nevada area is 2.65 people per dwelling unit (U.S. Census Bureau 2018-2022).

Las Vegas Nevada, 12 Unit Multi-Family Residential Condominium/Townhouse Building				
Baseline Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
36	Lavatory Faucet	X		209.9
24	Shower Head	X		795.0
12	Sink Faucet	X		699.6
36	Water Closet	X	X	305.3
12	Clothes Washer	X		228.0
12	Dishwasher	X		50.4
24	Hose bibbs	X	X	N/A
	Irrigation only	X	X	385
			Total	2,673.2

Table 7: Baseline Household Water Consumption per Day for Multi-Family unit in Las Vegas

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 1983 gallons or 74% of the total daily consumption.
Total daily non-potable consumption is 690 gallons or 26% of the total daily consumption.

3.3.4 Average 12 Unit Multi-Family Residential Building – Des Moines, Iowa

The average household size in the Des Moines, Iowa area is 2.34 people per dwelling unit (U.S. Census Bureau 2018-2022).

Des Moines Iowa, 12 Unit Multi-Family Residential Condominium/Townhouse Building				
Baseline Water Consumption per Day				
Qty	Water Fixture Type	Potable Supply	Non-Potable Supply	Gallons per Day
36	Lavatory Faucet	X		185.3
24	Shower Head	X		702.0
12	Sink Faucet	X		617.8
36	Water Closet	X	X	269.6
12	Clothes Washer	X		228.0
12	Dishwasher	X		50.4
24	Hose bibbs	X	X	N/A
	Irrigation only	X	X	385
			Total	2,438.1

Table 8: Baseline Household Water Consumption per Day for Multi-Family unit in Des Moines

If all potential non-potable water consumptions are separated for supply by an alt. water source:
Total daily potable water consumption is 1,783 gallons or 73% of the total daily consumption.
Total daily non-potable consumption is 655 gallons or 27% of the total daily consumption.

4.0 Potential Supplemental Water Sources for Residential Occupancies

This section focuses on exploring potential benefits through use of alternate, non-potable water streams in meeting the needs of the single family and multi-family households based on the baseline demand estimates tabulated in section 3 of this report.

4.1 On-Site Non-potable Water Reuse Systems

Onsite non-potable water reuse systems (ONWS) capture and treat water sources generated on site, including but not limited to a grey water system. The treated water is then distributed for reuse onsite or locally. Rainwater harvesting systems are considered separately from onsite non-potable water reuse systems.

Grey water is untreaded wastewater from bathtubs, showers, lavatories, clothes washers, and laundry tubs. Water that has been in contact with fixtures such as toilets, kitchen sinks, dishwashers, or similar sources where a potential for contamination exists is not classified as grey water.

Condensation is the formation of water or frost on a surface. Condensation occurs when warm, moisture-laden air encounters a colder surface such as a cooling coil. Residential homes equipped with HVAC cooling have an opportunity to capture and reuse the condensation that is generated at the cooling coil which has been traditionally discarded to sanitary drains or earth.

Ground water and/or foundation drain water may be collected in wells or storage vessels, treated and distributed for potable or non-potable usage.

4.2 Non-potable Rainwater Collection and Distribution Systems

Non-potable rainwater collection and distribution systems collect, store and treat rainwater primarily from above-ground impervious roofing surfaces. The treated water is then distributed for non-potable applications as permitted by the Authority Having Jurisdiction.

4.3 Reclaimed Water Systems

Reclaimed water is non-potable water produced from the treatment of wastewater by a facility or system licensed to produce water meeting the public health Authority Having Jurisdictions' water requirements for its intended use. This may also be referred to as recycled water.

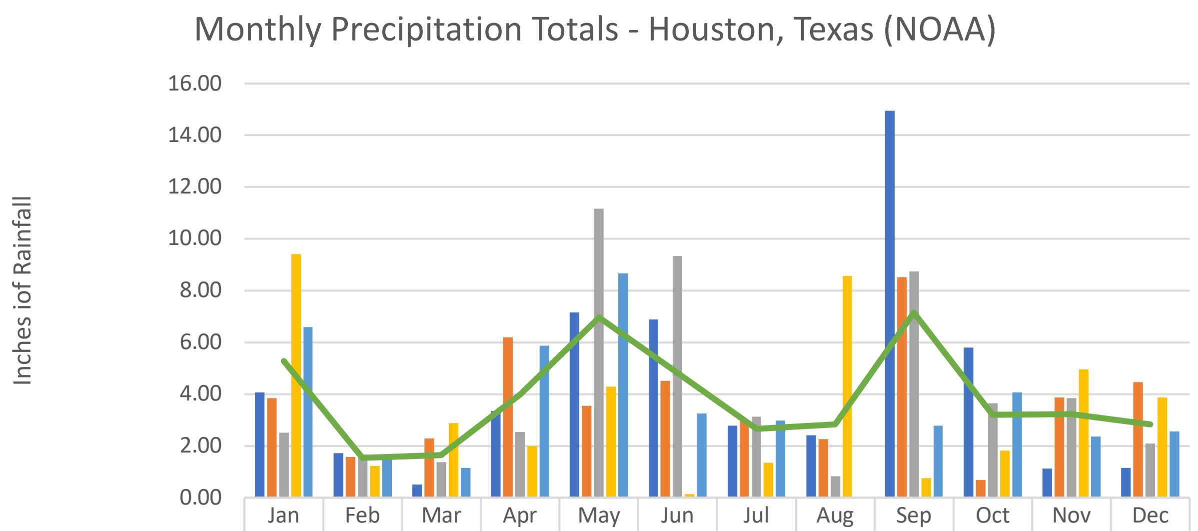
5.0 Potential Supplemental Water Sources Baseline Data

5.1 Rainwater Baseline Data

Rainwater data was compiled from National Oceanic and Atmospheric Administration (NOAA, 2024) weather data in monthly intervals for each city. Five-year averages from 2019 – 2023 were calculated and used in the modeling analysis. 80% collection efficiency was established for rainwater harvesting, based on the findings documented by a Rainwater Harvesting Systems

Technology Review study conducted by the Federal Energy Management Program of U.S. Department of Energy, which ranged the collection efficiency as 75% - 90%.

Houston – Texas: 5 Year Rainfall Averages (Monthly and Annually)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	4.08	1.73	0.50	3.36	7.16	6.88	2.79	2.42	14.95	5.80	1.12	1.14
2020	3.84	1.58	2.28	6.20	3.56	4.51	3.01	2.26	8.53	0.67	3.86	4.47
2021	2.51	1.66	1.38	2.54	11.17	9.33	3.13	0.83	8.73	3.64	3.85	2.10
2022	9.42	1.23	2.87	1.99	4.30	0.13	1.35	8.58	0.75	1.83	4.97	3.88
2023	6.58	1.49	1.15	5.87	8.66	3.24	2.98	0.01	2.77	4.07	2.36	2.57
5 Year Averages	5.29	1.54	1.64	3.99	6.97	4.82	2.65	2.82	7.15	3.20	3.23	2.83

2019 2020 2021 2022 2023 5 Year Averages

Figure III: Monthly Precipitation totals - Houston

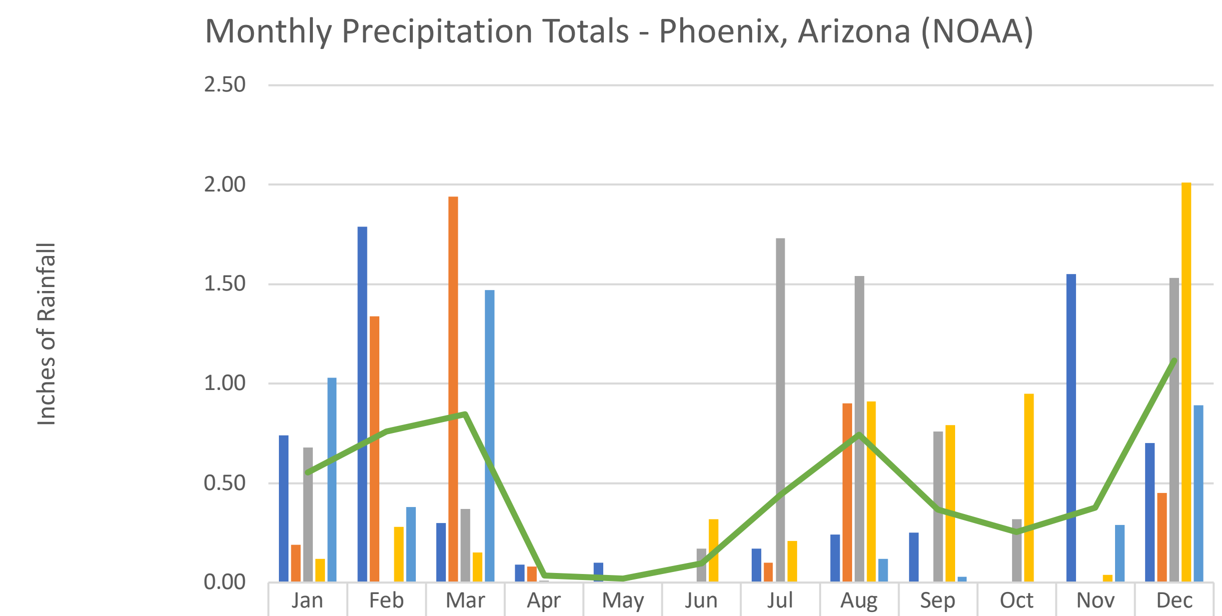
5.1.1 Single-Family Residential Home – Houston, Texas

Considering a 1,200 square foot average roof area for a single-family home, the 5-year average annual rainfall in Houston, Texas of 46.124 inches per year and a collection efficiency of 80% – this home could harvest a maximum annual potential of approximately 27,453 gallons per year.

5.1.2 Average 12 Unit Multi-Family Residential Building – Houston, Texas

Considering an average approximate building roof area of 7,500 square feet, the 5-year average annual rainfall in Houston, Texas of 46.124 inches per year and a collection efficiency of 80% – this example building could harvest a maximum annual potential of approximately 171,581 gallons per year. An additional 68,633 gallons per year could be harvested from the approximated 3,000 square foot roof area of the garage building, yielding a total maximum potential of approximately 240,214 gallons annually.

Phoenix, Arizona: 5 Year Rainfall Averages (Monthly and Annually)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	0.74	1.79	0.30	0.09	0.10	0.00	0.17	0.24	0.25	0.00	1.55	0.70
2020	0.19	1.34	1.94	0.08	0.00	0.00	0.10	0.90	0.00	0.00	0.00	0.45
2021	0.68	0.00	0.37	0.01	0.00	0.17	1.73	1.54	0.76	0.32	0.00	1.53
2022	0.12	0.28	0.15	0.00	0.00	0.32	0.21	0.91	0.79	0.95	0.04	2.01
2023	1.03	0.38	1.47	0.00	0.00	0.00	0.00	0.12	0.03	0.00	0.29	0.89
5 Year Averages	0.55	0.76	0.85	0.04	0.02	0.10	0.44	0.74	0.37	0.25	0.38	1.12

2019 2020 2021 2022 2023 5 Year Averages

Figure IV: Monthly Precipitation totals - Phoenix

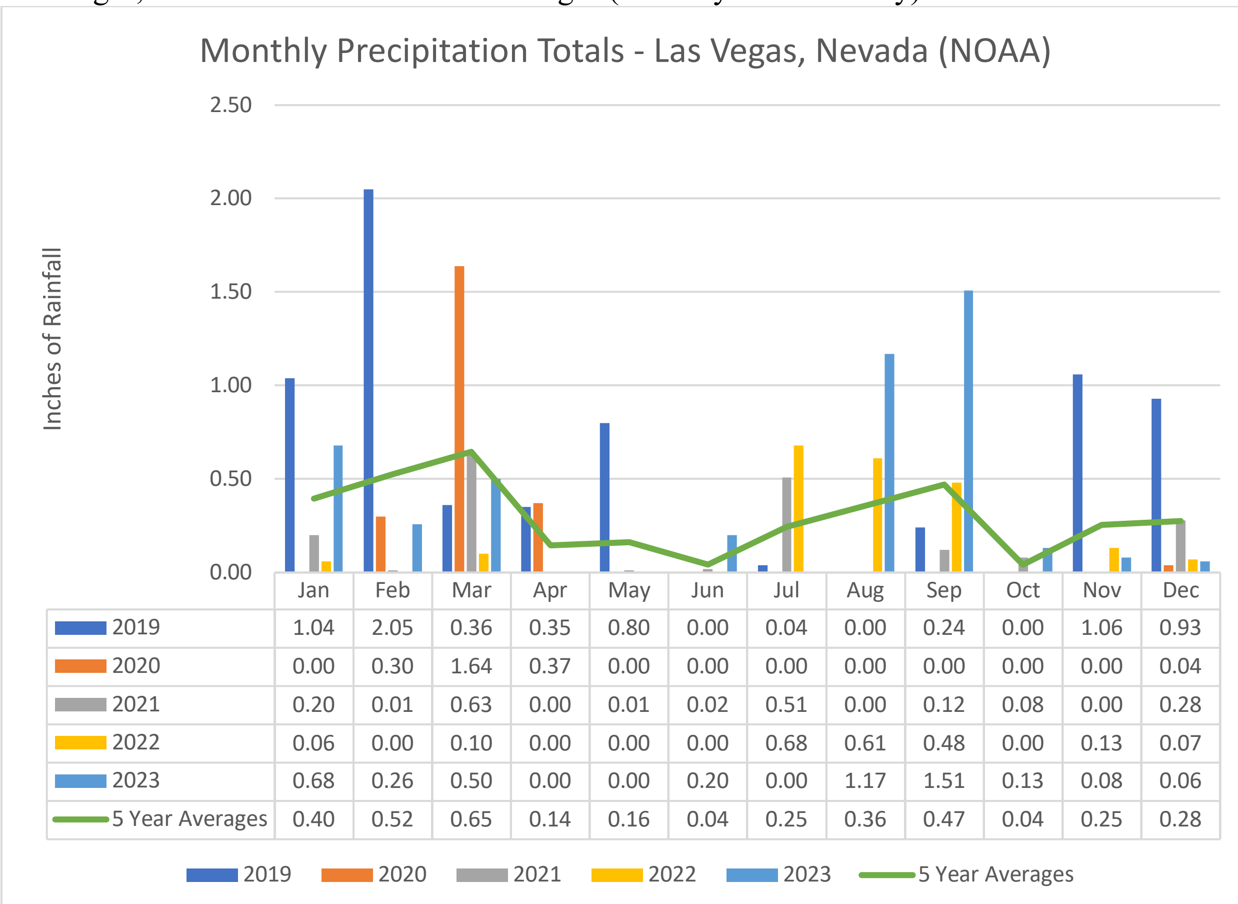
5.1.3 Single-Family Residential Home – Phoenix, Arizona

Considering a 1,200 square foot average roof area for a single-family home, the 5-year average annual rainfall in Phoenix, Arizona of 5.61 inches per year and a collection efficiency of 80% – this home could harvest a maximum annual potential of approximately 3,337 gallons per year.

5.1.4 Average 12 Unit Multi-Family Residential Building – Phoenix, Arizona

Considering an average approximate building roof area of 7,500 square feet, the 5-year average annual rainfall in Phoenix, Arizona of 5.606 inches per year and a collection efficiency of 80% – this example building could harvest a maximum annual potential of approximately 20,854 gallons per year. An additional 8,342 gallons per year could be harvested from the approximated 3,000 square foot roof area of the garage building, yielding a total maximum potential of approximately 29,196 gallons annually.

Las Vegas, Nevada: 5 Year Rainfall Averages (Monthly and Annually)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	1.04	2.05	0.36	0.35	0.80	0.00	0.04	0.00	0.24	0.00	1.06	0.93
2020	0.00	0.30	1.64	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
2021	0.20	0.01	0.63	0.00	0.01	0.02	0.51	0.00	0.12	0.08	0.00	0.28
2022	0.06	0.00	0.10	0.00	0.00	0.00	0.68	0.61	0.48	0.00	0.13	0.07
2023	0.68	0.26	0.50	0.00	0.00	0.20	0.00	1.17	1.51	0.13	0.08	0.06
5 Year Averages	0.40	0.52	0.65	0.14	0.16	0.04	0.25	0.36	0.47	0.04	0.25	0.28

Figure V: Monthly Precipitation totals - Las Vegas

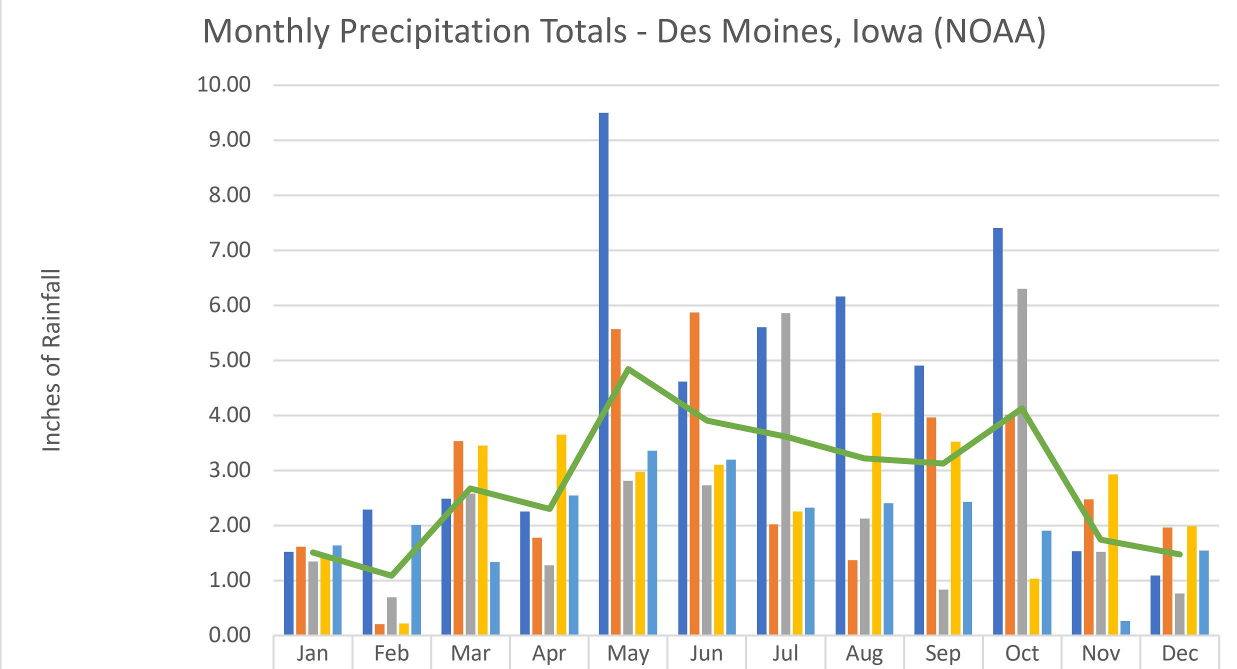
5.1.5 Single-Family Residential Home – Las Vegas, Nevada

Considering a 1,200 square foot average roof area for a single-family home, the 5-year average annual rainfall in Las Vegas, Nevada of 3.56 inches per year and a collection efficiency of 80% – this home could harvest a maximum annual potential of approximately 2,119 gallons per year.

5.1.6 Average 12 Unit Multi-Family Residential Building – Las Vegas, Nevada

Considering an average approximate building roof area of 7,500 square feet, the 5-year average annual rainfall in Las Vegas, Nevada of 3.560 inches per year and a collection efficiency of 80% – this example building could harvest a maximum annual potential of approximately 13,243 gallons per year. An additional 5,297 gallons per year could be harvested from the approximated 3,000 square foot roof area of the garage building, yielding a total maximum potential of approximately 18,540 gallons annually.

Des Moine, Iowa: 5 Year Rainfall Averages (Monthly and Annually)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	1.52	2.29	2.49	2.25	9.50	4.61	5.60	6.16	4.90	7.41	1.53	1.09
2020	1.61	0.21	3.53	1.78	5.57	5.87	2.02	1.37	3.96	4.01	2.48	1.96
2021	1.35	0.70	2.58	1.28	2.81	2.73	5.86	2.13	0.83	6.30	1.52	0.77
2022	1.44	0.22	3.45	3.65	2.97	3.10	2.25	4.04	3.52	1.03	2.93	1.99
2023	1.64	2.01	1.33	2.54	3.36	3.20	2.32	2.40	2.43	1.90	0.26	1.54
5 Year Averages	1.51	1.09	2.68	2.30	4.84	3.90	3.61	3.22	3.13	4.13	1.74	1.47

Figure VI: Monthly Precipitation totals - Des Moines

5.1.7 Single-Family Residential Home – Des Moines, Iowa

Considering a 1,200 square foot average roof area for a single-family home, the 5-year average annual rainfall in Des Moines, Iowa of 33.62 inches per year and a collection efficiency of 80% – this home could harvest a maximum annual potential of approximately 20,011 gallons per year.

5.1.8 Average 12 Unit Multi-Family Residential Building – Des Moines, Iowa

Considering an average approximate building roof area of 7,500 square feet, the 5-year average annual rainfall in Des Moines, Iowa of 33.620 inches per year and a collection efficiency of 80% – this example building could harvest a maximum annual potential of approximately 125,066 gallons per year. An additional 50,027 gallons per year could be harvested from the approximated 3,000 square foot roof area of the garage building, yielding a total maximum potential of approximately 175,093 gallons annually.

5.2 Baseline Condensation Data

Condensation data was developed by estimating the maximum household cooling using industry standards for capacity per square foot. The cooling capacity values would reflect traditional construction methods and insulation levels anticipated for each region. Cooling degree weather data for each city was then compiled and based on outside air temperatures, cooling load diversity factors were applied, and the corresponding cooling ton-hours were calculated. Using the formulas to calculate the psychometric of the initial and final conditions of air based on the methodology outlined in the ASHRAE 2021 Handbook, condensation rate ranging in 0.10 to 0.30 gallons per cooling ton-hour is typically achieved (Guz, K. 2005). In this study, condensation production was then calculated utilizing estimated average condensation rate of 0.20 gallons for every cooling ton-hour.

Condensate collection potential varies and is dependent upon the size and operation load of the air conditioning system, ambient temperature, and humidity. This study focuses on exemplifying the potential benefits for condensate harvesting in relevant climate zones. Condensate is considered free water and is produced when the need for water irrigation is high. Condensate water is considered a high-quality source of water, similar to distilled water, the pH is neutral to slightly acidic and the temperature is low.

5.2.1 Condensation Production Estimation per Household – Houston, Texas

The household HVAC cooling capacity has been estimated at 3.5 tons and will equate to 2,052 gallons of condensation production per year.

Houston, Texas						
Baseline Condensate Totals						
Month	Cooling Degree Days @65 deg F. Base Temp.	Monthly Ave. High Temp. (deg F.)	Cooling Load Diversity	Cooling Tons	Cooling Ton-Hours	HVAC Condensate (gal)
January	5	62	0.20	0.7	4	1
February	69	67	0.25	0.9	61	12
March	165	74	0.35	1.2	202	40
April	181	80	0.45	1.6	285	57
May	327	86	0.65	2.3	744	149
June	593	91	0.80	2.8	1,660	332
July	716	95	0.90	3.2	2,255	451
August	762	95	1.00	3.5	2,668	534
September	630	90	0.80	2.8	1,763	353
October	301	82	0.50	1.8	527	105
November	57	71	0.35	1.2	70	14
December	23	64	0.30	1.1	24	5
					Annual Total	2,052

Table 9: Baseline condensation totals - Houston

Weather data was obtained from the Houston International Airport weather station and the cooling degree days were calculated from a base temperature of 65 deg. F. (Degree Days, 2024).

5.2.2 Condensation Production Estimation per Household – Phoenix, Arizona

The household HVAC cooling capacity has been estimated at 3.5 tons and will equate to 2,872 gallons of condensation production per year.

Phoenix, Arizona						
Baseline Condensate Totals						
Month	Cooling Degree Days @65 deg F. Base Temp.	Monthly Ave. High Temp. (deg F.)	Cooling Load Diversity	Cooling Tons	Cooling Ton-Hours	HVAC Condensate (gal)
January	21	78.2	0.35	1.2	25	5
February	18	82.1	0.50	1.8	32	6
March	58	90.4	0.80	2.8	162	32
April	267	99	0.95	3.3	888	178
May	425	105.7	1.00	3.5	1,486	297
June	620	112.7	1.00	3.5	2,170	434
July	897	114.6	1.00	3.5	3,138	628
August	740	113.2	1.00	3.5	2,591	518
September	620	108.9	1.00	3.5	2,169	434
October	370	100.7	1.00	3.5	1,296	259
November	120	88.9	0.80	2.8	335	67
December	42	77.7	0.45	1.6	66	13
					Annual Total	2,872

Table 10: Baseline condensation totals - Phoenix

Weather data was obtained from the Phoenix Sky Harbor International Airport weather station and the cooling degree days were calculated from a base temperature of 65 deg. F. (Degree Days, 2024).

5.2.3 Condensation Production Estimation per Household – Las Vegas, Nevada

The household HVAC cooling capacity has been estimated at 3.5 tons and will equate to 2,702 gallons of condensation production per year.

Las Vegas Area, NV						
Baseline Condensate Totals						
Month	Cooling Degree Days @65 deg F. Base Temp.	Monthly Ave. High Temp. (deg F.)	Cooling Load Diversity	Cooling Tons	Cooling Ton-Hours	HVAC Condensate (gal)
January	4	68.7	0.40	1.4	6	1
February	2	74.2	0.50	1.8	3	1

March	9	84.3	0.65	2.3	20	4
April	223	93.6	0.90	3.2	704	141
May	456	101.8	1.00	3.5	1,595	319
June	573	110.1	1.00	3.5	2,005	401
July	1,052	112.9	1.00	3.5	3,683	737
August	796	110.3	1.00	3.5	2,786	557
September	507	105	1.00	3.5	1,773	355
October	276	94.6	0.90	3.2	868	174
November	37	80.6	0.50	1.8	65	13
December	3	67.9	0.40	1.4	4	1
					Annual Total	2,702

Table 11: Baseline condensation totals - Las Vegas

Weather data was obtained from the Las Vegas Harry Reid Airport weather station and the cooling degree days were calculated from a base temperature of 65 deg. F. (Degree Days, 2024).

5.2.4 Condensation Production Estimation per Household – Des Moines, Iowa

The household HVAC cooling capacity has been estimated at 3.0 tons and will equate to 687 gallons of condensation production per year.

Des Moines, Iowa						
Baseline Condensate Totals						
Month	Cooling Degree Days @65 deg F. Base Temp.	Monthly Ave. High Temp. (deg F.)	Cooling Load Diversity	Cooling Tons	Cooling Ton-Hours	HVAC Condensate (gal)
January	0	30	0.00	0.0	0	0
February	0	35	0.00	0.0	0	0
March	2	49	0.00	0.0	0	0
April	38	62	0.45	1.3	49	10
May	142	73	0.65	1.9	269	54
June	286	82	0.80	2.3	667	133
July	342	86	0.90	2.6	897	179
August	348	84	1.00	2.9	1,015	203
September	196	77	0.80	2.3	457	91
October	54	64	0.50	1.5	79	16
November	2	48	0.00	0.0	0	0
December	0	35	0.00	0.0	0	0
					Annual Total	687

Table 12: Baseline condensation totals - Des Moines

Weather data was obtained from the Des Moines International weather station and the cooling degree days were calculated from a base temperature of 65 deg. F. (Degree Days, 2024).

6.0 Water Conservation Measures

6.1 Water Efficient Fixtures

Measure Description – The baseline water fixtures are replaced with water efficient fixtures that comply with the new requirements in the 2021 International Water Conservation Code Provisions (IWCCP). Replacing water fixtures is a relatively low-cost measure and construction would be limited to the point of use locations.

Analysis and results – The baseline water consumption for single and multi-family homes was modeled using several resources and assumptions. The water efficient fixtures analysis utilized the same calculation methodology however fixture flow rates were adjusted accordingly. Water usage patterns are not changed between the baseline and proposed case.

The following tables represent the tabulated consumption volumes for single family and 12 dwelling multi-family residential buildings in each subject city.

Single Family Home Baseline Code Minimum Consumption Volumes – Houston, Texas

Houston Ammendments to the 2021 International Residential Code								
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate**		**Estimated Usage**		**Gallons per Person**		**Gallons per**	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	16.63	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	63.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	55.44	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd
Gallons per Household per Day							**177.63**	**gpd**
Gallons per Household per Year							**63,234.71**	**gpy**

Table 13: Single Family Home Baseline Code Minimum Consumption Volumes – Houston

Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Houston, Texas

2021 International Water Conservation Code Provisions								
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate**		**Estimated Usage per**		**Gallons per Person**		**Gallons per Household**	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.34	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	50.40	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	45.36	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd
Gallons per Household per Day							**143.65**	**gpd**
Gallons per Household per Year							**51,140.68**	**gpy**

Table 14: Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Houston

Single Family Home Baseline Code Minimum Consumption Volumes – Phoenix, Arizona

Phoenix Ammendments to the 2018 International Residential Code								
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate or**		**Estimated Usage per**		**Gallons per Person per**		**Gallons per**	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.69	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	67.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.96	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	25.73	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd
					Gallons per Household per Day		**192.58**	**gpd**
					Gallons per Household per Year		**68,557.06**	**gpy**

Table 15: Single Family Home Baseline Code Minimum Consumption Volumes – Phoenix

Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Phoenix, Arizona

2021 International Water Conservation Code Provisions								
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate**		**Estimated Usage per**		**Gallons per Person**		**Gallons per Household**	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	12.06	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.60	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	48.24	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd
					Gallons per Household per Day		**151.68**	**gpd**
					Gallons per Household per Year		**53,998.93**	**gpy**

Table 16: Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Phoenix

Single Family Home Baseline Code Minimum Consumption Volumes – Las Vegas, Nevada

Las Vegas Ammendments to the 2018 International Residential Code								
Plumbing Fixture or Fixture Fitting	**Maximum Flow Rate or Consumption**		**Estimated Usage per Day**		**Gallons per Person per Day**		**Gallons per Household per Day**	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.49	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	66.25	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.30	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	25.44	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd
					Gallons per Household per Day		**190.68**	**gpd**
					Gallons per Household per Year		**67,882.08**	**gpy**

Table 17: Single Family Home Baseline Code Minimum Consumption Volumes – Las Vegas

Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Las Vegas, Nevada

2021 International Water Conservation Code Provisions								
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.93	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.00	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	47.70	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd
Gallons per Household per Day							150.18	gpd
Gallons per Household per Year							53,463.01	gpy

Table 18: Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Las Vegas

Single Family Home Baseline Code Minimum Consumption Volumes – Des Moines, Iowa

Iowa Ammendments to the 2018 International Residential Code								
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	15.44	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	58.50	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	51.48	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	22.46	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd
Gallons per Household per Day							171.09	gpd
Gallons per Household per Year							60,907.33	gpy

Table 19: Single Family Home Baseline Code Minimum Consumption Volumes – Des Moines

Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Des Moines, Iowa

2021 International Water Conservation Code Provisions								
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	10.53	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	46.80	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	42.12	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd
Gallons per Household per Day							134.62	gpd
Gallons per Household per Year							47,925.15	gpy

Table 20: Single Family Home Consumption Volumes Based on Proposed Water Conservation Provisions – Des Moines

12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Houston, Texas

Houston Ammendments to the 2021 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	16.63	gpd	199.58	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	63.00	gpd	756.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	55.44	gpd	665.28	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	232.24	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	228.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	50.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									2,131.51	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									758,816.56	gpy

Table 21: 12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Houston

12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Houston, Texas

2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.34	gpd	136.08	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	50.40	gpd	604.80	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	45.36	gpd	544.32	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	19.35	gpd	232.24	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	168.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	38.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									1,723.84	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									613,688.18	gpy

Table 22: 12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Houston

12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Phoenix, Arizona

Phoenix Ammendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.69	gpd	212.26	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	67.00	gpd	804.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.96	gpd	707.52	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	25.73	gpd	308.74	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	228.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	50.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									2,310.91	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									822,684.67	gpy

Table 23: 12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Phoenix

12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Phoenix, Arizona

2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	12.06	gpd	144.72	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.60	gpd	643.20	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	48.24	gpd	578.88	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.58	gpd	246.99	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	168.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	38.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									1,820.19	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									647,987.21	gpy

Table 24: 12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Phoenix

12 Dwelling Unit Multi-Family Baseline Code Minimum vs Proposed Water Conservation Provisions – Las Vegas, Nevada

Las Vegas Ammendments to the 2018 International Residential Code										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	17.49	gpd	209.88	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	66.25	gpd	795.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	58.30	gpd	699.60	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	25.44	gpd	305.28	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	228.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	50.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									2,288.16	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									814,584.96	gpy

Table 25: 12 Dwelling Unit Multi-Family Baseline Code Minimum vs Proposed Water Conservation Provisions – Las Vegas

12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Las Vegas, Nevada

2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	11.93	gpd	143.10	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	53.00	gpd	636.00	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	47.70	gpd	572.40	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	20.35	gpd	244.22	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	168.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	38.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									1,802.12	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									641,556.14	gpy

Table 26: 12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Las Vegas

12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Des Moines, Iowa

Iowa Ammendments to the 2018 International Residential Code											
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	2.20	gpm	3.0	min	6.60	gpd	15.44	gpd	185.33	gpd
Shower Head	2.50	gpm	10.0	min	25.00	gpd	58.50	gpd	702.00	gpd
Sink Faucet	2.20	gpm	10.0	min	22.00	gpd	51.48	gpd	617.76	gpd
Water Closet	1.60	gpf	6.0	flush	9.60	gpd	22.46	gpd	269.57	gpd
Clothes Washer	19.00	gpl	1.0	load	-	gpd	19.00	gpd	228.00	gpd
Dishwasher	4.20	gpc	1.0	cycle	-	gpd	4.20	gpd	50.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									2,053.06	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									730,887.94	gpy

Table 27: 12 Dwelling Unit Multi-Family Baseline Code Minimum Consumption Volumes – Des Moines

12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Des Moines, Iowa

2021 International Water Conservation Code Provisions										
Plumbing Fixture or Fixture Fitting	Maximum Flow Rate or Consumption		Estimated Usage per Day		Gallons per Person per Day		Gallons per Household per Day		Gallons per Multi-Family Building per Day	
Lavatory Faucet	1.50	gpm	3.0	min	4.50	gpd	10.53	gpd	126.36	gpd
Shower Head	2.00	gpm	10.0	min	20.00	gpd	46.80	gpd	561.60	gpd
Sink Faucet	1.80	gpm	10.0	min	18.00	gpd	42.12	gpd	505.44	gpd
Water Closet	1.28	gpf	6.0	flush	7.68	gpd	17.97	gpd	215.65	gpd
Clothes Washer	14.00	gpl	1.0	load	-	gpd	14.00	gpd	168.00	gpd
Dishwasher	3.20	gpc	1.0	cycle	-	gpd	3.20	gpd	38.40	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Day									1,615.45	gpd
Gallons per 12 Unit Multi-Family Residential Condominium/Townhouse Building per Year									575,101.77	gpy

Table 28: 12 Dwelling Unit Multi-Family Consumption Volumes Based on Proposed Water Conservation Provisions – Des Moines

6.2 Hot Water Systems- Residential

Measure Description – Service hot water systems including water heaters, hot water pipe insulation, heated water circulation piping and temperature maintenance systems requirements are provided to minimize the volume of water which may cool within the distribution piping. Any volume of hot water which has cooled within the piping system is typically wasted by running the plumbing fixture to flush the cooled water out to allow for the hot water to be expelled from the fixture outlet at the desired temperature.

Analysis and results – Impact on residential plumbing systems other than centralized hot water systems within single-family and multi-family residential buildings is not significant due to the inherently small pipe sizes and short lengths of run within a single-family home or multi-family home dwelling unit with a local water heater. The IWCCP, aims to provide further limitations to maximum volume of water within the piping between the source of hot water and the fixtures of 64 oz. where the hot water source is a water heater and 24 oz. where the hot water source is a circulation loop or an electrically heat-traced pipe , which will likely produce water conservation benefits. However, as noted in earlier sections of this report, hot water systems and piping network optimization benefits were intentionally excluded in this phase of the study, but will be evaluated further with more in-depth analysis when coupled with energy conservation benefit evaluation in later phase of this investigation.

6.3 Rainwater Harvesting

Rainwater collection and distribution systems sized for maximum rainfall potential harvesting are provided to offset the non-potable site consumption. Minimal filtration systems or treatment is required since all rainwater collection systems serve non-potable fixtures.

While rainfall totals vary greatly by region, this measure can still offer water conservation in most locations. The equipment investment and intended usage of rainwater would increase in regions with higher annual rainfall totals.

Rainwater in most regions is considered to be relatively pure, with low mineral content, however contamination can occur from the catchment surface materials or environmental deposits forming or expelled onto the catchment surface. This makes rainwater a good candidate for potable water if treated properly, like that of well water. If regulations were developed and enforced for individual water filtration and purification systems to allow to produce potable water from captured rainwater, this measure may be extremely beneficial in climates with moderate annual rainfall rates. However, due to the unpredictability and inconsistency of rainfall, this system should not be considered as the sole source of water and will require interconnection from a generally uninterruptable water supply to serve as a backup water source.

Storage tank size/volume would be the most limiting factor for a residential rainwater harvesting system. A large system would likely require a large volume exterior above or below grade storage tank.

Small system – Single family home with 1,200 square foot roof collection surface area. The system would provide non-potable water for indoor water closet flushing and exterior landscaping purposes. The system would include the filtration and disinfection equipment, storage tank, booster pump with hydromechanical tank, controls, and distribution piping from the outlet of the tank to supply all water closets and irrigation systems. As this non-potable system is not considered reliable to always meet the usage demand, interconnection of a reliable water source such as municipal water is also required with a backflow preventer to protect the municipal water supply.

Large system – 12 Unit Multi-Family Residential Condominium/Townhouse Building with 7,500 square foot roof collection surface area plus an additional 3,000 square foot garage roof catchment area. The system would serve non-potable water for indoor water closet flushing and exterior landscaping purposes. The system would include the filtration and disinfection equipment, storage tank, booster pump with hydromechanical tank, controls, and distribution piping from the outlet of the tank to supply all water closets and irrigation systems. The non-potable water closet supply water would be a central system throughout the building. As this non-potable system is not considered reliable to always meet the usage demand, interconnection of a reliable water source such as municipal water is also required with a backflow preventer to protect the municipal water supply.

Analysis and results – Monthly rainfall collection profiles were developed using the NOAA weather data, collection surface area, and efficiency factors. Comparing the monthly non-potable demand consumption to the available rainwater collected and stored provided the estimated monthly and annual water savings. The small and large rainwater collection systems utilized the same calculation methodology. Each system was modeled to maximize the rainwater harvesting savings potential per city.

Small and Large Rainwater Harvesting Collection Systems – Houston, Texas

Small System			Large System	
Roof Area (sq. ft.)	1,200		Roof Area (sq. ft.)	10,500
Rain water collected (gal)	27,453		Rain water collected (gal)	240,214
Rain water consumed (gal)	35,317		Rain water consumed (gal)	225,911
Water Savings per Year (gal)	27,453		Water Savings per Year (gal)	240,214

Houston, TX - Small System

Month	Rainwater Consumption			Rainwater Harvesting					Estimated Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	600	2,391	2,991	5.286	1,200	0.62	0.8	3,146	3,146
February	561	2,237	2,798	1.538	1,200	0.62	0.8	915	915
March	600	2,391	2,991	1.636	1,200	0.62	0.8	974	974
April	581	2,314	2,895	3.992	1,200	0.62	0.8	2,376	2,376
May	600	2,391	2,991	6.97	1,200	0.62	0.8	4,149	4,149
June	581	2,314	2,895	4.818	1,200	0.62	0.8	2,868	2,868
July	600	2,391	2,991	2.652	1,200	0.62	0.8	1,578	1,578
August	600	2,391	2,991	2.82	1,200	0.62	0.8	1,678	1,678
September	581	2,314	2,895	7.146	1,200	0.62	0.8	4,253	4,253
October	600	2,391	2,991	3.202	1,200	0.62	0.8	1,906	1,906
November	581	2,314	2,895	3.232	1,200	0.62	0.8	1,924	1,924
December	600	2,391	2,991	2.832	1,200	0.62	0.8	1,686	1,686
			35,317					27,453	27,453

Houston, TX - Large System

Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	7,200	11,935	19,135	5.286	10,500	0.62	0.8	27,529	27,529
February	6,735	11,165	17,900	1.538	10,500	0.62	0.8	8,010	8,010
March	7,200	11,935	19,135	1.636	10,500	0.62	0.8	8,520	8,520
April	6,967	11,550	18,517	3.992	10,500	0.62	0.8	20,790	20,790
May	7,200	11,935	19,135	6.97	10,500	0.62	0.8	36,300	36,300
June	6,967	11,550	18,517	4.818	10,500	0.62	0.8	25,092	25,092
July	7,200	11,935	19,135	2.652	10,500	0.62	0.8	13,812	13,812
August	7,200	11,935	19,135	2.82	10,500	0.62	0.8	14,687	14,687
September	6,967	11,550	18,517	7.146	10,500	0.62	0.8	37,216	37,216
October	7,200	11,935	19,135	3.202	10,500	0.62	0.8	16,676	16,676
November	6,967	11,550	18,517	3.232	10,500	0.62	0.8	16,832	16,832
December	7,200	11,935	19,135	2.832	10,500	0.62	0.8	14,749	14,749
			225,911					240,214	240,214

Table 29: Small and Large Rainwater Harvesting Collection Systems – Houston

Maximum potential rainwater harvesting in Houston, Texas produces a 100% usable volume of water for non-potable uses for an average single-family home assuming that adequately sized storage cistern is integrated into design and installed at the property. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 78% annually.

Maximum potential rainwater harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building with an additional surplus of approximately 14,000 gallons annually which demonstrates the potential to be applied toward supplementing the potable water supply of the building with proper treatment and regulations.

Small and Large Rainwater Harvesting Collection Systems – Phoenix, Arizona

Small System	
Roof Area (sq. ft.)	1,200
Rain water collected (gal)	3,337
Rain water consumed (gal)	37,757
Water Savings per Year (gal)	3,337

Large System	
Roof Area (sq. ft.)	10,500
Rain water collected (gal)	29,196
Rain water consumed (gal)	255,190
Water Savings per Year (gal)	29,196

Phoenix, AZ - Small System									
Month	Rainwater Consumption			Rainwater Harvesting					Estimated Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	807	2,391	3,198	0.552	1,200	0.62	0.8	329	329
February	755	2,237	2,992	0.758	1,200	0.62	0.8	451	451
March	807	2,391	3,198	0.846	1,200	0.62	0.8	504	504
April	781	2,314	3,095	0.036	1,200	0.62	0.8	21	21
May	807	2,391	3,198	0.02	1,200	0.62	0.8	12	12
June	781	2,314	3,095	0.098	1,200	0.62	0.8	58	58
July	807	2,391	3,198	0.442	1,200	0.62	0.8	263	263
August	807	2,391	3,198	0.742	1,200	0.62	0.8	442	442
September	781	2,314	3,095	0.366	1,200	0.62	0.8	218	218
October	807	2,391	3,198	0.254	1,200	0.62	0.8	151	151
November	781	2,314	3,095	0.376	1,200	0.62	0.8	224	224
December	807	2,391	3,198	1.116	1,200	0.62	0.8	664	664
			37,757					3,337	3,337

Phoenix, AZ - Large System									
Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	9,679	11,935	21,614	0.552	10,500	0.62	0.8	2,875	2,875
February	9,055	11,165	20,220	0.758	10,500	0.62	0.8	3,948	3,948
March	9,679	11,935	21,614	0.846	10,500	0.62	0.8	4,406	4,406
April	9,367	11,550	20,917	0.036	10,500	0.62	0.8	187	187
May	9,679	11,935	21,614	0.02	10,500	0.62	0.8	104	104
June	9,367	11,550	20,917	0.098	10,500	0.62	0.8	510	510
July	9,679	11,935	21,614	0.442	10,500	0.62	0.8	2,302	2,302
August	9,679	11,935	21,614	0.742	10,500	0.62	0.8	3,864	3,864
September	9,367	11,550	20,917	0.366	10,500	0.62	0.8	1,906	1,906
October	9,679	11,935	21,614	0.254	10,500	0.62	0.8	1,323	1,323
November	9,367	11,550	20,917	0.376	10,500	0.62	0.8	1,958	1,958
December	9,679	11,935	21,614	1.116	10,500	0.62	0.8	5,812	5,812
			255,190					29,196	29,196

Table 30: Small and Large Rainwater Harvesting Collection Systems – Phoenix

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for an average single-family home without any surplus. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 9% annually.

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 11% annually.

The landscape irrigation consumption would vary greatly based on property size, homeowner lifestyles and plant species used in landscaping. Large diversity in irrigation estimates directly impacts the potable to non-potable site profiles and therefore percent reductions of municipal water for non-potable uses.

Small and Large Rainwater Harvesting Collection Systems – Las Vegas Area, Nevada

Small System	
Roof Area (sq. ft.)	1,200
Rain water collected (gal)	2,119
Rain water consumed (gal)	37,965
Water Savings per Year (gal)	2,119

Large System	
Roof Area (sq. ft.)	10,500
Rain water collected (gal)	18,540
Rain water consumed (gal)	257,693
Water Savings per Year (gal)	18,540

Las Vegas, NV - Small System

Month	Rainwater Consumption			Rainwater Harvesting					Estimated Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	824	2,391	3,216	0.396	1,200	0.62	0.8	236	236
February	771	2,237	3,008	0.524	1,200	0.62	0.8	312	312
March	824	2,391	3,216	0.646	1,200	0.62	0.8	384	384
April	798	2,314	3,112	0.144	1,200	0.62	0.8	86	86
May	824	2,391	3,216	0.162	1,200	0.62	0.8	96	96
June	798	2,314	3,112	0.044	1,200	0.62	0.8	26	26
July	824	2,391	3,216	0.246	1,200	0.62	0.8	146	146
August	824	2,391	3,216	0.356	1,200	0.62	0.8	212	212
September	798	2,314	3,112	0.47	1,200	0.62	0.8	280	280
October	824	2,391	3,216	0.042	1,200	0.62	0.8	25	25
November	798	2,314	3,112	0.254	1,200	0.62	0.8	151	151
December	824	2,391	3,216	0.276	1,200	0.62	0.8	164	164
			37,965					2,119	2,119

Las Vegas, NV- Large System

Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	9,891	11,935	21,826	0.396	10,500	0.62	0.8	2,062	2,062
February	9,253	11,165	20,418	0.524	10,500	0.62	0.8	2,729	2,729
March	9,891	11,935	21,826	0.646	10,500	0.62	0.8	3,364	3,364
April	9,572	11,550	21,122	0.144	10,500	0.62	0.8	750	750
May	9,891	11,935	21,826	0.162	10,500	0.62	0.8	844	844
June	9,572	11,550	21,122	0.044	10,500	0.62	0.8	229	229
July	9,891	11,935	21,826	0.246	10,500	0.62	0.8	1,281	1,281
August	9,891	11,935	21,826	0.356	10,500	0.62	0.8	1,854	1,854
September	9,572	11,550	21,122	0.47	10,500	0.62	0.8	2,448	2,448
October	9,891	11,935	21,826	0.042	10,500	0.62	0.8	219	219
November	9,572	11,550	21,122	0.254	10,500	0.62	0.8	1,323	1,323
December	9,891	11,935	21,826	0.276	10,500	0.62	0.8	1,437	1,437
			257,693					18,540	18,540

Table 31: Small and Large Rainwater Harvesting Collection Systems – Las Vegas

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for an average single-family home without any surplus. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 6% annually.

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 7% annually.

The landscape irrigation consumption would vary greatly based on property size, homeowner lifestyles and plant species used in landscaping. Large diversity in irrigation estimates directly impacts the potable to non-potable site profiles and therefore percent reductions of municipal water for non-potable uses.

Small and Large Rainwater Harvesting Collection Systems – Des Moines, Iowa

Small System	
Roof Area (sq. ft.)	1,200
Rain water collected (gal)	20,011
Rain water consumed (gal)	36,666
Water Savings per Year (gal)	20,011

Large System	
Roof Area (sq. ft.)	10,500
Rain water collected (gal)	175,093
Rain water consumed (gal)	242,102
Water Savings per Year (gal)	175,093

Des Moines, IA - Small System									
Month	Rainwater Consumption			Rainwater Harvesting					Estimated Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	714	2,391	3,106	1.512	1,200	0.62	0.8	900	900
February	668	2,237	2,905	1.086	1,200	0.62	0.8	646	646
March	714	2,391	3,106	2.676	1,200	0.62	0.8	1,593	1,593
April	691	2,314	3,005	2.3	1,200	0.62	0.8	1,369	1,369
May	714	2,391	3,106	4.842	1,200	0.62	0.8	2,882	2,882
June	691	2,314	3,005	3.902	1,200	0.62	0.8	2,322	2,322
July	714	2,391	3,106	3.61	1,200	0.62	0.8	2,149	2,149
August	714	2,391	3,106	3.22	1,200	0.62	0.8	1,917	1,917
September	691	2,314	3,005	3.128	1,200	0.62	0.8	1,862	1,862
October	714	2,391	3,106	4.13	1,200	0.62	0.8	2,458	2,458
November	691	2,314	3,005	1.744	1,200	0.62	0.8	1,038	1,038
December	714	2,391	3,106	1.47	1,200	0.62	0.8	875	875
			36,666					20,011	20,011

Des Moines, IA - Large System									
Month	Rainwater Consumption			Rainwater Harvesting					Water Savings (gal)
	Indoor (non-potable)	Landscape (non-potable)	Total demand (non-potable)	Average rainfall (Inches/mo)	Collection surface size (sq. ft.)	Gallons/ft^2 collection coefficient	Efficiency factor	Rainfall collected (80% efficiency)	
January	8,571	11,935	20,506	1.512	10,500	0.62	0.8	7,874	7,874
February	8,018	11,165	19,183	1.086	10,500	0.62	0.8	5,656	5,656
March	8,571	11,935	20,506	2.676	10,500	0.62	0.8	13,937	13,937
April	8,294	11,550	19,844	2.3	10,500	0.62	0.8	11,978	11,978
May	8,571	11,935	20,506	4.842	10,500	0.62	0.8	25,217	25,217
June	8,294	11,550	19,844	3.902	10,500	0.62	0.8	20,322	20,322
July	8,571	11,935	20,506	3.61	10,500	0.62	0.8	18,801	18,801
August	8,571	11,935	20,506	3.22	10,500	0.62	0.8	16,770	16,770
September	8,294	11,550	19,844	3.128	10,500	0.62	0.8	16,291	16,291
October	8,571	11,935	20,506	4.13	10,500	0.62	0.8	21,509	21,509
November	8,294	11,550	19,844	1.744	10,500	0.62	0.8	9,083	9,083
December	8,571	11,935	20,506	1.47	10,500	0.62	0.8	7,656	7,656
			242,102					175,093	175,093

Table 32: Small and Large Rainwater Harvesting Collection Systems – Des Moines

Maximum potential rainwater harvesting in Des Moine, Iowa produces a 100% usable volume of water towards non-potable uses for an average single-family home without any surplus. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 55% annually.

Maximum potential rainwater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building without any surplus. This would reduce the amount of municipal water supplied to the building for non-potable water uses by an average of 72% annually.

The landscape irrigation consumption would vary greatly based on property size, homeowner lifestyles and plant species used in landscaping. Large diversity in irrigation estimates directly impacts the potable to non-potable site profiles and therefore percent reductions of municipal water for non-potable uses.

In summary, as demonstrated by the analysis above for the four subject cities, harvested rainwater can be an alternate water supply stream meeting the non-potable water demands as well as in some cases, having the potential to produce surplus water volume which may also be utilized towards potable water needs with proper treatment. Of course, proper water balance computations will need to be undertaken by the design engineers in coordination with landscape architects when assessing design approaches.

6.4 Grey Water Harvesting

Measure Description – Grey water harvesting, and distribution systems sized for maximum harvesting potential are provided to offset the non-potable site consumption. Minimal filtration systems or treatment is required since all rainwater collection systems serve non-potable fixtures.

Grey water collection systems were modeled for two different scenarios varying the quantity of fixtures, people, and storage tank requirements:

Small system – Single Family Home: The system would serve non-potable water closets only and landscape irrigation. The system would include drain piping from each fixture (bathtub, showers, lavatories, laundry tub, and HVAC equipment) to be directed to an onsite storage tank. A filtration and disinfection system, and pump would be provided to provide code minimum treatment in compliance with NSF/ANSI 350 Standard (Onsite Residential and Commercial Water Reuse Treatment Systems) that is referenced in the IWCCP. Distribution piping from the outlet of the tank, through a pressure booster pump with a hydromechanical tank, would be extended into the home to serve all water closets with supply water. A supply branch pipe would also be extended and connected into supply piping that serves landscape irrigation.

Large system – 12 Unit Multi-Family Residential Condominium/Townhouse Building: The system would serve non-potable water closets only and landscape irrigation. The system would include drain piping from each fixture (bathtub, showers, lavatories, laundry tub, and HVAC equipment) to be directed to an onsite storage tank. A filtration and disinfection system, and pump would provide code minimum treatment in compliance with NSF 350/ANSI Standard (Onsite and Residential and Commercial Water Reuse Treatment Systems) that is referenced in the IWCCP. Distribution piping from the outlet of the tank, through a pressure booster pump with a hydromechanical tank would be extended into the home to serve all water closets with supply water. A supply branch pipe would also be extended and connected into supply piping that serves landscape irrigation.

Analysis and results– – Monthly grey water consumption and grey water harvesting profiles were developed using the previously established single and or multi-family baselines. Both systems were modeled to maximize the grey water harvesting savings potential.

Comparing the grey water consumption to the available grey water collected and stored provided the estimated monthly and annual water savings. The grey water systems models produced the following results:

Small and Large Grey Water Harvesting Systems – Houston, Texas

Baseline Grey Water Harvesting				
Plumbing Fixture	**Gallons per Day**		**Gallons per Year**	
Lavatory Faucet	16.6	gpd	6,071	gpy
Shower Head	63.0	gpd	22,995	gpy
Clothes Washer	19.0	gpd	6,935	gpy
	98.6	**gpd**	**36,001**	**gpy**
HVAC Condensate			1,038	gpy
		Total	**37,039**	**gpy**

Baseline Grey Water Site Consumption				
Plumbing Fixture	**Gallons per Day**		**Gallons per Year**	
Water Closet	19.4	gpd	7,064	gpy
Irrigation	77.1	gpd	28,156	gpy
		Total	**35,220**	**gpy**

Small System		Large System	
Grey water collected	28,922	Grey water collected	303,740
Grey water consumption	35,317	Grey water consumption	225,911
Water Savings per Year (gal)	35,317	Water Savings per Year (gal)	225,911

Small System									
	Grey Water Consumption			**Grey Water Harvesting**					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Single Family Grey Water Consumption (gal)**	**Grey water collected (75% efficiency)**	**HVAC Condensate (gal)**	**Grey water collected (90% efficiency)**	**Total grey water harvested (gal)**	**Water Savings (gal)**
January	600	2,391	2,991	3,058	2,293	0.8	0.7	2,294	2,294
February	561	2,237	2,798	2,860	2,145	12.1	10.9	2,156	2,156
March	600	2,391	2,991	3,058	2,293	40.4	36.3	2,330	2,330
April	581	2,314	2,895	2,959	2,219	57.0	51.3	2,271	2,271
May	600	2,391	2,991	3,058	2,293	148.8	133.9	2,427	2,427
June	581	2,314	2,895	2,959	2,219	331.9	298.7	2,518	2,518
July	600	2,391	2,991	3,058	2,293	451.0	405.9	2,699	2,699
August	600	2,391	2,991	3,058	2,293	533.5	480.2	2,773	2,773
September	581	2,314	2,895	2,959	2,219	352.5	317.3	2,536	2,536
October	600	2,391	2,991	3,058	2,293	105.5	94.9	2,388	2,388
November	581	2,314	2,895	2,959	2,219	14.0	12.6	2,232	2,232
December	600	2,391	2,991	3,058	2,293	4.9	4.4	2,298	2,298
		Annual Total	**35,317**				**Annual Total**	**28,922**	**28,922**

Large System									
	Grey Water Consumption			**Grey Water Harvesting**					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Mulit-Family Grey Water Consumption (gal)**	**Grey water collected (75% efficiency)**	**HVAC Condensate (gal)**	**Grey water collected (90% efficiency)**	**Total grey water harvested (gal)**	**Water Savings (gal)**
January	7,200	11,935	19,135	36,691	23,849	9	8	23,857	23,857
February	6,735	11,165	17,900	34,324	22,311	146	131	22,442	22,442
March	7,200	11,935	19,135	36,691	23,849	485	436	24,285	24,285
April	6,967	11,550	18,517	35,508	23,080	685	616	23,696	23,696
May	7,200	11,935	19,135	36,691	23,849	1,785	1,607	25,456	25,456
June	6,967	11,550	18,517	35,508	23,080	3,983	3,585	26,665	26,665
July	7,200	11,935	19,135	36,691	23,849	5,411	4,870	28,720	28,720
August	7,200	11,935	19,135	36,691	23,849	6,402	5,762	29,611	29,611
September	6,967	11,550	18,517	35,508	23,080	4,230	3,807	26,887	26,887
October	7,200	11,935	19,135	36,691	23,849	1,266	1,139	24,989	24,989
November	6,967	11,550	18,517	35,508	23,080	168	151	23,231	23,231
December	7,200	11,935	19,135	36,691	23,849	59	53	23,902	23,902
		Annual Total	**225,911**				**Annual Total**	**303,740**	**303,740**

Table 33: Small and Large Grey Water Harvesting Systems – Houston

Maximum potential grey water harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for an average single-family home. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 82% annually.

Maximum potential grey water harvesting in Houston, Texas produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building with an additional surplus of approximately 78,000 gallons annually.

Small and Large Grey Water Harvesting Systems – Phoenix, Arizona

Baseline Grey Water Harvesting				
Plumbing Fixture	Gallons per Day		Gallons per Year	
Lavatory Faucet	17.7	gpd	6,456	gpy
Shower Head	67.0	gpd	24,455	gpy
Clothes Washer	19.0	gpd	6,935	gpy
	103.7	**gpd**	**37,846**	**gpy**
HVAC Condensate			1,038	gpy
		Total	**38,884**	**gpy**

Baseline Grey Water Site Consumption				
Plumbing Fixture	Gallons per Day		Gallons per Year	
Water Closet	25.7	gpd	9,391	gpy
Irrigation	77.1	gpd	28,156	gpy
		Total	**37,547**	**gpy**

Small System		Large System	
Grey water collected	31,047	Grey water collected	327,022
Grey water consumption	37,650	Grey water consumption	253,907
Water Savings per Year (gal)	37,650	Water Savings per Year (gal)	253,907

Small System									
	Grey Water Consumption			Grey Water Harvesting					
Month	Water Closets (gal)	Irrigation (gal)	Total (gal)	Single Family Grey Water Consumption (gal)	Grey water collected (75% efficiency)	HVAC Condensate (gal)	Grey water collected (90% efficiency)	Total grey water harvested (gal)	Water Savings (gal)
January	798	2,391	3,189	3,214	2,411	5.1	4.6	2,415	2,415
February	746	2,237	2,983	3,007	2,255	6.3	5.7	2,261	2,261
March	798	2,391	3,189	3,214	2,411	32.4	29.2	2,440	2,440
April	772	2,314	3,086	3,111	2,333	177.6	159.9	2,493	2,493
May	798	2,391	3,189	3,214	2,411	297.2	267.5	2,678	2,678
June	772	2,314	3,086	3,111	2,333	434.1	390.7	2,724	2,724
July	798	2,391	3,189	3,214	2,411	627.6	564.8	2,976	2,976
August	798	2,391	3,189	3,214	2,411	518.1	466.3	2,877	2,877
September	772	2,314	3,086	3,111	2,333	433.7	390.3	2,723	2,723
October	798	2,391	3,189	3,214	2,411	259.1	233.2	2,644	2,644
November	772	2,314	3,086	3,111	2,333	67.1	60.4	2,393	2,393
December	798	2,391	3,189	3,214	2,411	13.2	11.9	2,423	2,423
		Annual Total	**37,650**				**Annual Total**	**31,047**	**31,047**

Large System									
	Grey Water Consumption			Grey Water Harvesting					
Month	Water Closets (gal)	Irrigation (gal)	Total (gal)	Mulit-Family Grey Water Consumption (gal)	Grey water collected (75% efficiency)	HVAC Condensate (gal)	Grey water collected (90% efficiency)	Total grey water harvested (gal)	Water Savings (gal)
January	9,571	11,935	21,506	38,572	25,072	61	55	25,127	25,127
February	8,953	11,165	20,118	36,083	23,454	76	68	23,523	23,523
March	9,571	11,935	21,506	38,572	25,072	389	350	25,422	25,422
April	9,262	11,550	20,812	37,328	24,263	2,131	1,918	26,181	26,181
May	9,571	11,935	21,506	38,572	25,072	3,567	3,210	28,282	28,282
June	9,262	11,550	20,812	37,328	24,263	5,209	4,688	28,951	28,951
July	9,571	11,935	21,506	38,572	25,072	7,531	6,778	31,849	31,849
August	9,571	11,935	21,506	38,572	25,072	6,218	5,596	30,668	30,668
September	9,262	11,550	20,812	37,328	24,263	5,205	4,684	28,947	28,947
October	9,571	11,935	21,506	38,572	25,072	3,110	2,799	27,870	27,870
November	9,262	11,550	20,812	37,328	24,263	805	725	24,988	24,988
December	9,571	11,935	21,506	38,572	25,072	159	143	25,215	25,215
		Annual Total	**253,907**				**Annual Total**	**327,022**	**327,022**

Table 34: Small and Large Grey Water Harvesting Systems – Phoenix

Maximum potential grey water harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for an average single-family home. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 82% annually.

Maximum potential rainwater harvesting in Phoenix, Arizona produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building with an additional surplus of approximately 73,000 gallons annually.

Small and Large Grey Water Harvesting Systems – Las Vegas, Nevada

Baseline Grey Water Site Consumption				
Plumbing Fixture	**Gallons per Day**		**Gallons per Year**	
Water Closet	25.4	gpd	9,286	gpy
Irrigation	77.1	gpd	28,156	gpy
		Total	**37,442**	**gpy**

Small System		**Large System**	
Grey water collected	30,634	Grey water collected	322,488
Grey water consumption	37,544	Grey water consumption	252,642
Water Savings per Year (gal)	37,544	Water Savings per Year (gal)	252,642

Small System									
	Grey Water Consumption			**Grey Water Harvesting**					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Single Family Grey Water Consumption (gal)**	**Grey water collected (75% efficiency)**	**HVAC Condensate (gal)**	**Grey water collected (90% efficiency)**	**Total grey water harvested (gal)**	**Water Savings (gal)**
January	789	2,391	3,180	3,185	2,389	1.2	1.1	2,390	2,390
February	738	2,237	2,975	2,979	2,235	0.6	0.6	2,235	2,235
March	789	2,391	3,180	3,185	2,389	4.0	3.6	2,392	2,392
April	763	2,314	3,077	3,082	2,312	140.7	126.7	2,438	2,438
May	789	2,391	3,180	3,185	2,389	319.1	287.2	2,676	2,676
June	763	2,314	3,077	3,082	2,312	401.0	360.9	2,673	2,673
July	789	2,391	3,180	3,185	2,389	736.6	662.9	3,052	3,052
August	789	2,391	3,180	3,185	2,389	557.1	501.4	2,890	2,890
September	763	2,314	3,077	3,082	2,312	354.6	319.2	2,631	2,631
October	789	2,391	3,180	3,185	2,389	173.6	156.3	2,545	2,545
November	763	2,314	3,077	3,082	2,312	13.0	11.7	2,323	2,323
December	789	2,391	3,180	3,185	2,389	0.8	0.7	2,389	2,389
		Annual Total	**37,544**				**Annual Total**	**30,634**	**30,634**

Large System									
	Grey Water Consumption			**Grey Water Harvesting**					
Month	**Water Closets (gal)**	**Irrigation (gal)**	**Total (gal)**	**Mulit-Family Grey Water Consumption (gal)**	**Grey water collected (75% efficiency)**	**HVAC Condensate (gal)**	**Grey water collected (90% efficiency)**	**Total grey water harvested (gal)**	**Water Savings (gal)**
January	9,464	11,935	21,399	38,219	24,843	15	13	24,856	24,856
February	8,853	11,165	20,018	35,754	23,240	8	7	23,247	23,247
March	9,464	11,935	21,399	38,219	24,843	48	43	24,885	24,885
April	9,158	11,550	20,708	36,986	24,041	1,689	1,520	25,561	25,561
May	9,464	11,935	21,399	38,219	24,843	3,829	3,446	28,288	28,288
June	9,158	11,550	20,708	36,986	24,041	4,812	4,330	28,372	28,372
July	9,464	11,935	21,399	38,219	24,843	8,839	7,955	32,798	32,798
August	9,464	11,935	21,399	38,219	24,843	6,686	6,017	30,860	30,860
September	9,158	11,550	20,708	36,986	24,041	4,255	3,830	27,871	27,871
October	9,464	11,935	21,399	38,219	24,843	2,084	1,875	26,718	26,718
November	9,158	11,550	20,708	36,986	24,041	156	140	24,181	24,181
December	9,464	11,935	21,399	38,219	24,843	10	9	24,851	24,851
		Annual Total	**252,642**				**Annual Total**	**322,488**	**322,488**

Table 35: Small and Large Grey Water Harvesting Systems – Las Vegas

Maximum potential grey water harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for an average single-family home. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 82% annually.

Maximum potential rainwater harvesting in Las Vegas, Nevada produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building with an additional surplus of approximately 70,000 gallons annually.

Maximum potential grey water harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for an average single-family home. This would reduce the amount of municipal water supplied to the home for non-potable water uses by an average of 72% annually.

Maximum potential rainwater harvesting in Des Moines, Iowa produces a 100% usable volume of water towards non-potable uses for 12-unit multi-family residential building with an additional surplus of approximately 51,000 gallons annually.

Based on the analysis demonstrated in sections 6.3-Rainwater Harvesting and 6.4-Grey Water Harvesting, it is important to highlight that there is strong potential for implementing these measures individually or collectively depending on multiple regionally and design specific factors. The landscape irrigation consumption may vary greatly based on property size, homeowner lifestyles and plant species and landscape design implemented. Large diversity in irrigation estimates directly impacts the potable to non-potable site profiles and therefore the projected surplus of grey water captured for non-potable uses. Therefore, harvesting storage and treatment capacities can be optimized with proper water balance computations at each property to produce the most favorable conservation outcomes.

Small and Large Grey Water Harvesting Systems – Des Moines, Iowa

Baseline Grey Water Harvesting				
Plumbing Fixture	**Gallons per Day**		**Gallons per Year**	
Lavatory Faucet	15.4	gpd	5,637	gpy
Shower Head	58.5	gpd	21,353	gpy
Clothes Washer	19.0	gpd	6,935	gpy
	92.9	**gpd**	**33,925**	**gpy**
HVAC Condensate			1,038	gpy
		Total	**34,963**	**gpy**

Baseline Grey Water Site Consumption				
Plumbing Fixture	**Gallons per Day**		**Gallons per Year**	
Water Closet	22.5	gpd	8,199	gpy
Irrigation	77.1	gpd	28,156	gpy
		Total	**36,355**	**gpy**

Small System		**Large System**	
Grey water collected	26,131	Grey water collected	272,755
Grey water consumption	36,455	Grey water consumption	239,572
Water Savings per Year (gal)	36,455	Water Savings per Year (gal)	239,572

Small System

Month	Grey Water Consumption: Water Closets (gal)	Grey Water Consumption: Irrigation (gal)	Grey Water Consumption: Total (gal)	Grey Water Harvesting: Single Family Grey Water Consumption (gal)	Grey Water Harvesting: Grey water collected (75% efficiency)	Grey Water Harvesting: HVAC Condensate (gal)	Grey Water Harvesting: Grey water collected (90% efficiency)	Grey Water Harvesting: Total grey water harvested (gal)	Water Savings (gal)
January	696	2,391	3,088	2,881	2,161	0.0	0.0	2,161	2,161
February	651	2,237	2,889	2,695	2,022	0.0	0.0	2,022	2,022
March	696	2,391	3,088	2,881	2,161	0.0	0.0	2,161	2,161
April	674	2,314	2,988	2,788	2,091	9.8	8.9	2,100	2,100
May	696	2,391	3,088	2,881	2,161	53.8	48.4	2,209	2,209
June	674	2,314	2,988	2,788	2,091	133.4	120.1	2,211	2,211
July	696	2,391	3,088	2,881	2,161	179.5	161.5	2,322	2,322
August	696	2,391	3,088	2,881	2,161	203.1	182.8	2,344	2,344
September	674	2,314	2,988	2,788	2,091	91.4	82.3	2,174	2,174
October	696	2,391	3,088	2,881	2,161	15.8	14.3	2,175	2,175
November	674	2,314	2,988	2,788	2,091	0.0	0.0	2,091	2,091
December	696	2,391	3,088	2,881	2,161	0.0	0.0	2,161	2,161
		Annual Total	**36,455**				**Annual Total**	**26,131**	**26,131**

Large System

Month	Grey Water Consumption: Water Closets (gal)	Grey Water Consumption: Irrigation (gal)	Grey Water Consumption: Total (gal)	Grey Water Harvesting: Mulit-Family Grey Water Consumption (gal)	Grey Water Harvesting: Grey water collected (75% efficiency)	Grey Water Harvesting: HVAC Condensate (gal)	Grey Water Harvesting: Grey water collected (90% efficiency)	Grey Water Harvesting: Total grey water harvested (gal)	Water Savings (gal)
January	8,357	11,935	20,292	34,575	22,474	0	0	22,474	22,474
February	7,817	11,165	18,982	32,345	21,024	0	0	21,024	21,024
March	8,357	11,935	20,292	34,575	22,474	0	0	22,474	22,474
April	8,087	11,550	19,637	33,460	21,749	118	106	21,855	21,855
May	8,357	11,935	20,292	34,575	22,474	646	581	23,055	23,055
June	8,087	11,550	19,637	33,460	21,749	1,601	1,441	23,190	23,190
July	8,357	11,935	20,292	34,575	22,474	2,154	1,939	24,412	24,412
August	8,357	11,935	20,292	34,575	22,474	2,437	2,193	24,667	24,667
September	8,087	11,550	19,637	33,460	21,749	1,097	987	22,736	22,736
October	8,357	11,935	20,292	34,575	22,474	190	171	22,645	22,645
November	8,087	11,550	19,637	33,460	21,749	0	0	21,749	21,749
December	8,357	11,935	20,292	34,575	22,474	0	0	22,474	22,474
		Annual Total	**239,572**				**Annual Total**	**272,755**	**272,755**

Table 36: Small and Large Grey Water Harvesting Systems – Des Moines

7.0 Scaling to City-Scale: Water Conservation Outcomes

This in-depth prediction explores the complex relationships between water demand, conservation initiatives, and environmental factors that will shape our water landscape in the upcoming years. When demonstrating aggregated benefits realized from application of multiple conservation provisions, correction factors were applied to ensure realistic outcomes. For example, if adoption of more water efficient plumbing fixtures was considered together with grey water treatment, storage and reuse, a 23% reduction in grey water harvesting potential was integrated based on reduced flow from more efficient plumbing fixtures.

The water conservation gains calculated for single-family and low-rise multi-family residential buildings are scaled up to obtain citywide conservation outcomes using numerical modeling that incorporates city-specific census data on occupancy and the existing housing stock, as well as forecasts of future new homes. However, it's important to note that it is not plausible to expect all homes in a city to adopt these provisions simultaneously or instantaneously. Instead, in our calculations, we assume that all new homes constructed in the future will adhere to the IWCCP, while a portion of existing homes will gradually adopt them through renovations over time. Sales volume data for newly constructed homes from 2018 to the end of 2023 were utilized to obtain a 6-year forecast employing the exponential smoothing (ETS) algorithm for each city under study. The resulting new construction trajectories for each city are depicted in the graphs below. These forecasts serve as key input in computing the future projections of the water conservation volumes achievable through compliance with the IWCCP at citywide scales in various geographic locations with different climatic and geological characteristics.

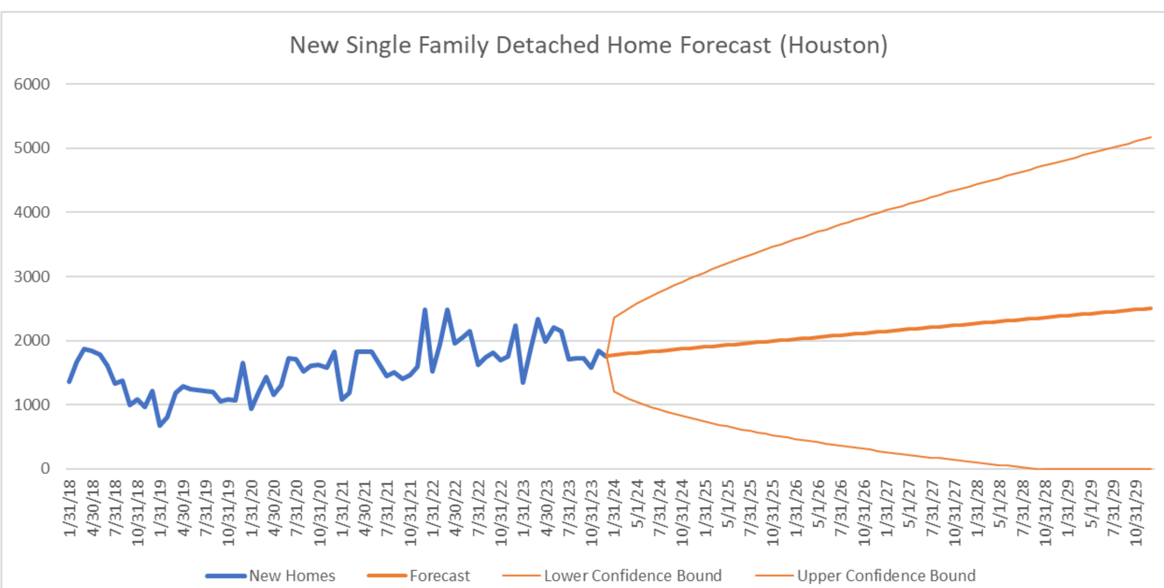


Figure VII: Historic New Home Construction Trend and Projected Future Trajectory - Houston

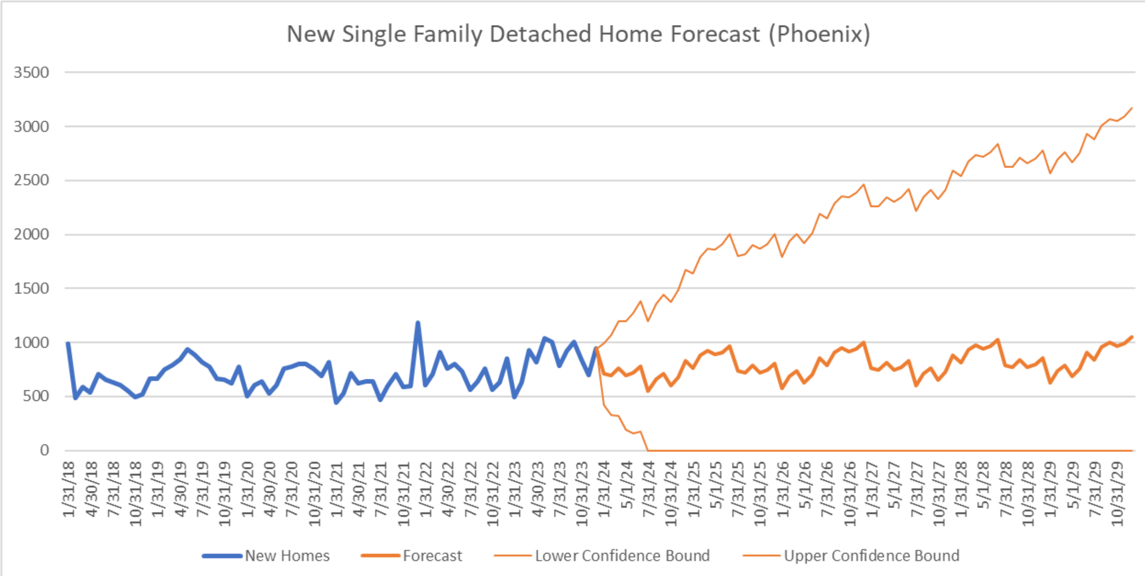


Figure VIII: Historic New Home Construction Trend and Projected Future Trajectory - Phoenix

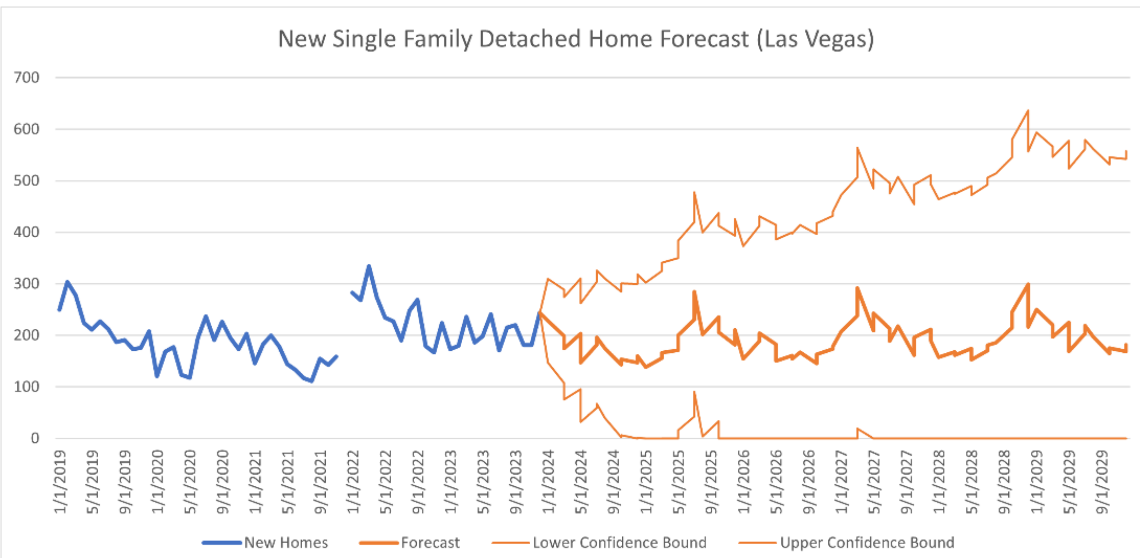


Figure IX: Historic New Home Construction Trend and Projected Future Trajectory - Las Vegas

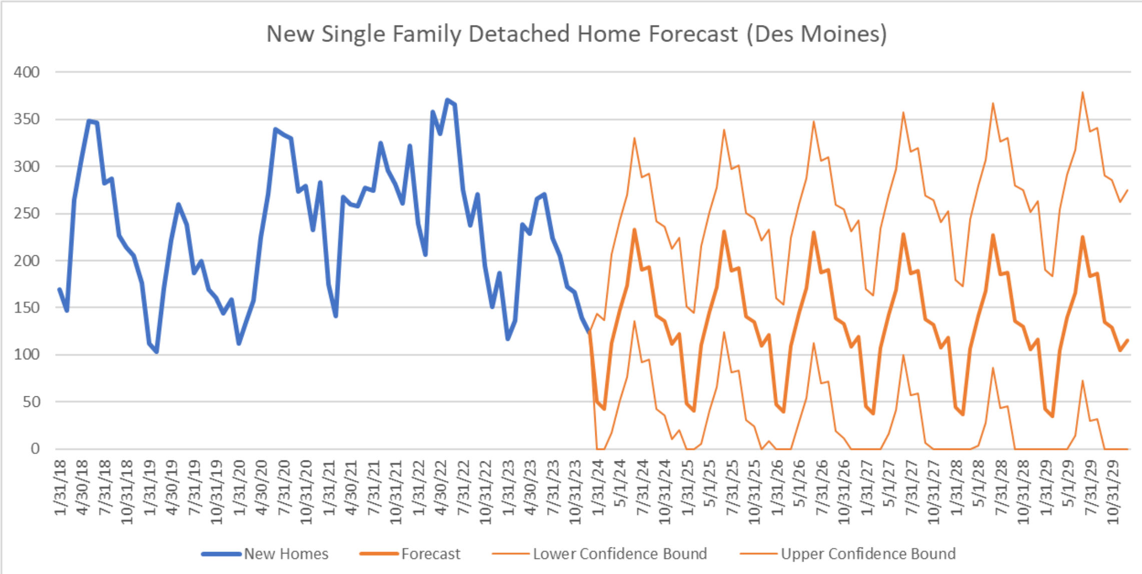


Figure X: Historic New Home Construction Trend and Projected Future Trajectory - Des Moines

While the results documented in this study are based on assumption that the historic new home construction trajectory remains the same in the years ahead, the upper and lower curves in each city's trajectory represent the potential for significantly higher or perhaps lower construction activity outcomes. The future projections of water conservation amounts are developed based on the nominal forecast amounts depicted in the above graphs under three scenarios. In the first scenario (NH), the projections are constructed assuming that only new homes will adopt the IWCCP measures. Under the second (NH1%) and third (NH5%) scenarios it is assumed that in addition to the new homes, a portion of the existing housing stock adopts these measures through renovation with rates of 1% and 5% per year respectively. The projected savings are broken down into four measures: rainwater harvesting, condensate harvesting, adoption of water efficient plumbing fixtures and grey water harvesting.

We note that the water conservation volumes are optimized based on the consumption demand when the aggregate amounts are obtained in the rest of the study. Specifically, if we let x and y denote the water demand and the potential conservation amounts as calculated in Section 6 respectively, we determine the final conservation amount by $\min(x, y)$. This adjustment is needed particularly in grey water conservation.

In order to exemplify relative cost implications for the conservation measures explored in this study, the following rough cost estimates were considered:

1. Cost of adopting water efficient plumbing fixtures: $3,200 / unit
2. Cost of grey water treatment, storage and use: $10,000 / unit
3. Cost of rainwater and condensate harvesting: $10,000 / building

Moreover, we employ the estimated cost of $12.60 for combined water & wastewater per 1,000 gallons reported by EPA. While there are many benefits of residential water conservation that are evident or can be measured directly, some benefits are hard to estimate.

Sections below demonstrate and discuss our findings.

7.1 Houston Scaled-up Water Conservation Analysis

Figure XI presents the annual water conservation forecast for the City of Houston under the three scenarios introduced earlier. With only new single-family homes adopting all the IWCCP measures, the aggregate water conservation levels are projected to increase from 0.6 billion gallons in Year 1 (2024) to 7.4 billion gallons by the end of Year 6 (2029) totalling 23.3 billion gallons over a 6-year period. In this scenario, the annual water conservation amount increases approximately with a rate of 1.4 billion gallons per year. With 1% of the existing and non-adopting homes joining this group of homes every year, the annual water conservation amount increases from 0.8 to 8.6 billion gallons from Year 1 to Year 6 with a total gain of 27.6 billion gallons over a 6-year period. In the realm of new homes along with 5% of the existing homes adapting the noted conservation provisions, represented by the steadfast gray line, there's a notable upward trajectory. Starting at a robust 1.6 billion gallons in Year 1, conservation measures steadily climb, reaching an impressive level of 13.3 billion gallons by Year 6. This scenario results in a total water conservation of 44.1 billion gallons over a 6-year period.

These diverging trends underscore the multifaceted nature of water conservation endeavours, highlighting the need for tailored strategies to address the varied needs of different segments within our communities.

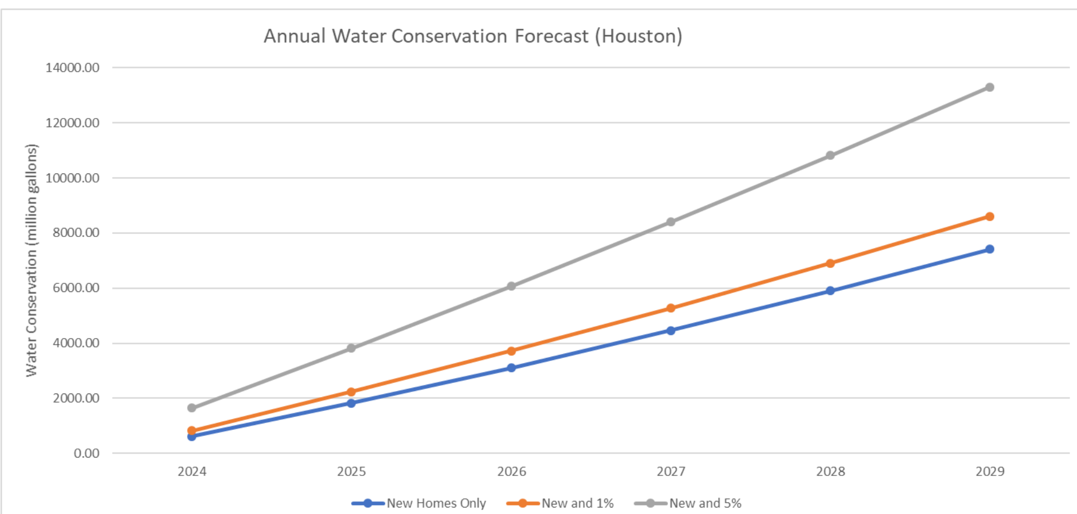


Figure XI: *Annual Aggregate Water Conservation Forecast for City of Houston*

Figure XII provides a more detailed projection for the NH1% scenario for the City of Houston, where the conservation amount under each category is represented by a separate color-coded stack. This projection paints a vivid picture of the multifaceted strategies employed to preserve the available water resources. It is clear from the figure that, for city of Houston, rainwater harvesting, adoption of more efficient plumbing fixtures and grey water harvesting stand out as high impact water conservation provisions. Condensate water harvesting, although not as impactful, can further contribute to preservation of water resources. When coupled together, these converging and diverging trends underscore the necessity for a comprehensive approach to water conservation, embracing both natural processes and human interventions. Notably, Figure XII highlights that if all new homes adopt water conservation measures moving forward along with just 1 percent of existing homes in city of Houston, such effort may reach a water conservation level of over eight billion gallons per year within the next six years.

These intertwined trends underscore the complexity of water conservation strategies, urging for a comprehensive and adaptive approach to safeguard our water resources for the future. Notably, if all new homes in Houston adopt water conservation measures along with 5 percent of old homes, annual water conservation levels are expected to exceed thirteen billion gallons of water in the next six years as depicted in Figure XIII. As such, significant strides can be made towards ensuring the sustainability of our water supply by adoption of the proposed provisions.

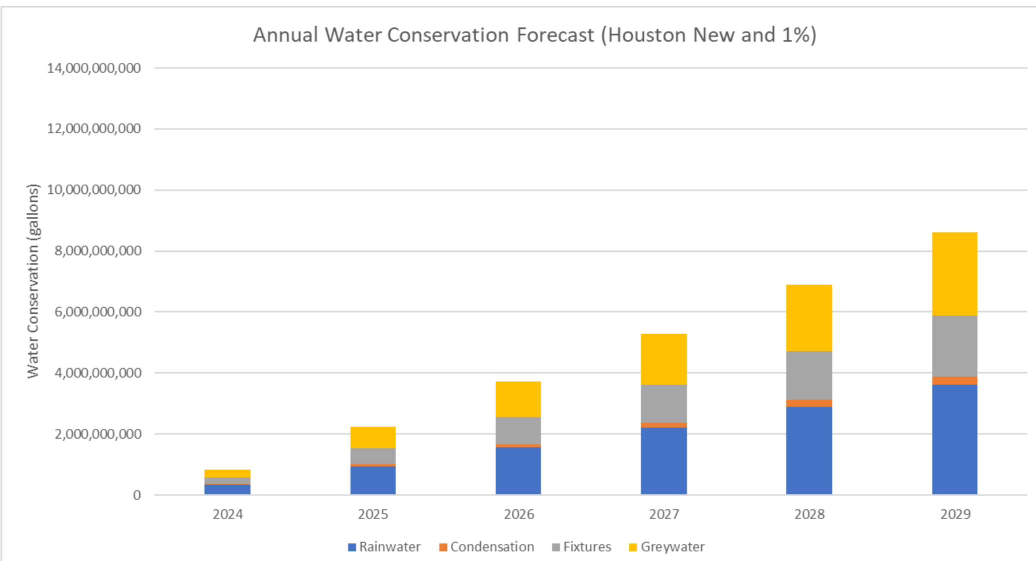


Figure XIII: *Annual Water Conservation Forecast (Houston NH1% Scenario)*

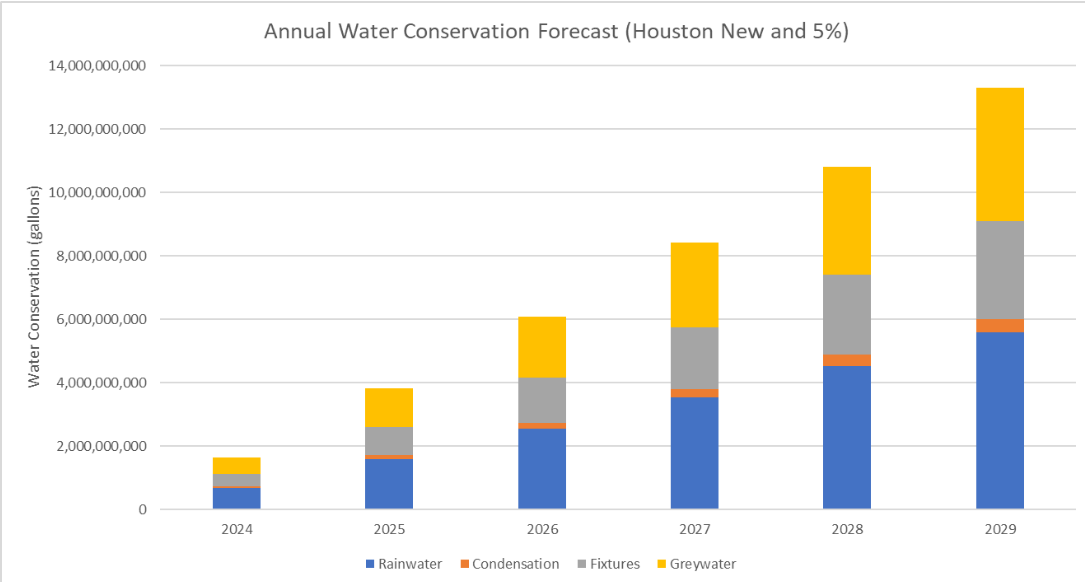


Figure XIIII: *Annual Water Conservation Forecast (Houston NH 5% Scenario)*

Table 37 details the annual aggregate water conservation amounts across all single-family homes in Houston assuming every one of them adopts the provisions. These numbers provide the potential savings for the existing homes. The potential for water conservation within existing homes presents a promising outlook, with various avenues contributing to significant savings. Rainfall harvesting offers a substantial contribution of 8.57 billion gallons, complemented by condensation capture at 0.64 billion gallons. Additionally, the conservation efforts focused on potable fixtures yield 4.77 billion gallons, while harnessing other grey water sources contributes 7.97 billion gallons. Altogether, these initiatives hold the potential to conserve a remarkable total of 15.67 billion gallons of water. When considering both new and existing homes over a span of six years, the aggregate water conservation projections unveil even more substantial figures.

Potential Rainfall Harvest	8.57 billion
Condensation	0.64 billion
Fixtures (Potable)	4.77 billion
Other Grey Water Harvested	7.97 billion
Total	**15.67 billion**

Table 37: Annual Potential Aggregate Water Conservation in Houston (gallons - Existing Homes)

Aggregate water conservation amounts across all scenarios over a 6-year period are summarized in Table 38. With scenarios ranging from new homes alone to incorporating renovations in existing homes, the estimates soar, reaching up to 44.07 billion gallons under the NH5% scenario. Furthermore, understanding the cost implications of conserving each gallon underscores the economic feasibility of these measures. As shown in Table 38, with a rainwater and condensation conservation system, a one-time investment of $338.93 results in 1000 gallons savings every year. Hence, assuming a typical mortgage term of 30 years, conserving 1000 gallons a year yields a cost of $11.30 (338.93/30) per year in that timeframe. These values are $254.20 and $8.47 for fixture-base systems and $483.33 and $16.11 for grey water harvesting. In total, and over the course of a typical mortgage, these measures preserve a gallon of water for between 1 and 2 cents. These insights underscore the cost-effectiveness of investing in water conservation initiatives, highlighting the potential for substantial savings while fostering a more sustainable water future.

New Homes Only (NH)	23.3 billion
New Homes and 1% of Existing Homes Renovated (NH1%)	27.6 billion
New Homes and 5% of Existing Homes Renovated (NH5%)	44.1 billion
One Time Cost of Conserving 1000 gallon per year (Rain and Cond)	$338.93
One Time Cost of Conserving 1000 gallon per year (Fixtures)	$254.20
One Time Cost of Conserving 1000 gallon per year (Grey Water Harvest)	$483.33

Table 38: Aggregate Water Conservation (gallons - New and Existing Homes over 6 Years)

7.2 Phoenix Scaled-up Water Conservation Analysis

The data trends revealed in the annual water conservation forecast for Phoenix paint a compelling picture of evolving conservation efforts within the region as depicted in Figure XIV. The blue line, symbolizing water conservation in new homes exclusively, demonstrates a steep upward trajectory, signalling substantial growth in water-saving initiatives within newly constructed properties. Meanwhile, the orange and gray lines depict scenarios incorporating both new homes and incremental increases in conservation across existing properties, with moderate growth rates observed. These trends underscore a collective effort towards enhancing water conservation practices, with varying degrees of impact depending on the conservation scenario. While the gray line exhibits the most aggressive goals, the other scenarios strike a balance between growth and sustainability, reflecting a nuanced approach to resource management. With only new single-family homes adopting all the IWCCP measures, the aggregate water conservation levels are projected to increase from 0.2 billion gallons in Year 1 (2024) to 2.25 billion gallons by the end of Year 6 (2029) totalling 7.25 billion gallons over a 6-year period. In this scenario, the annual water conservation amount increases approximately with a rate of 0.4 billion gallons per year. With 1% of the existing and non-adopting homes joining this group of homes every year, the annual water conservation amount increases from 0.36 to 3.19 billion gallons from Year 1 to Year 6 with a total gain of 10.58 billion gallons over a 6-year period. In the case of new homes along with 5% of the existing homes adapting the noted conservation provisions, there's a notable upward trajectory in Phoenix as well. Starting at 1 billion gallons in Year 1, conservation measures reach 6.9 billion gallons by Year 6. This scenario results in a total water conservation of 23.55 billion gallons over a 6-year period.

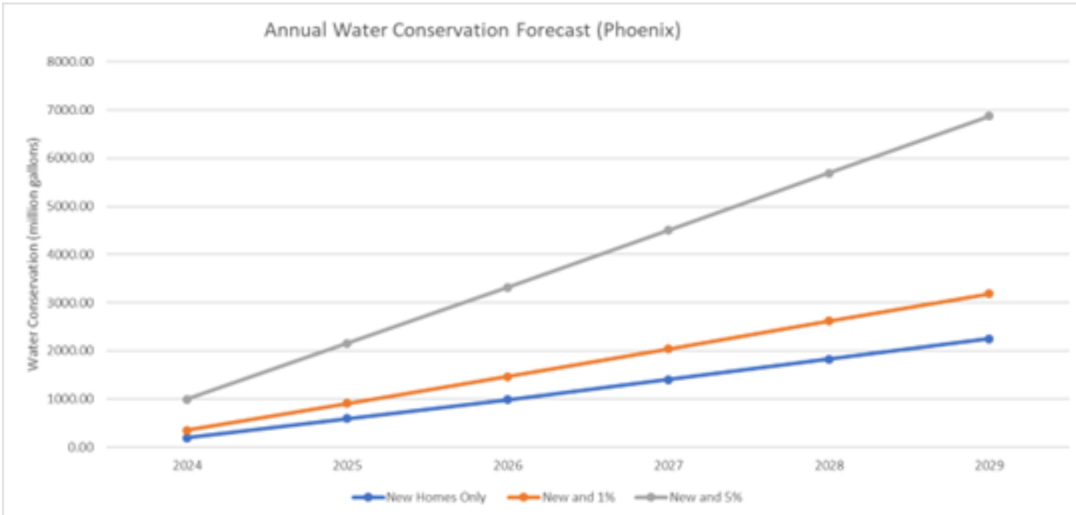


Figure XIV: *Phoenix Scaled-up Water Conservation Analysis*

It is apparent from Figure XV that due to the more arid climate in this region, rainwater harvesting and condensation water recovery are not the most impactful water conservation provisions for Phoenix. Meanwhile, the water efficient fixture-related conservation efforts and grey water harvesting for treatment and reuse emerge as major sources of conservation for Phoenix. Condensation water and rainwater harvesting, although not as impactful, can further contribute to preservation of water resources. These intertwined trends underscore the diverse strategies and evolving dynamics within water conservation, emphasizing the importance of adaptive approaches to ensure sustainable water management for the future. Notably, if all new homes in Phoenix adopt water conservation measures along with 1 percent of old homes, significant strides can be made towards ensuring the sustainability of our water supply.

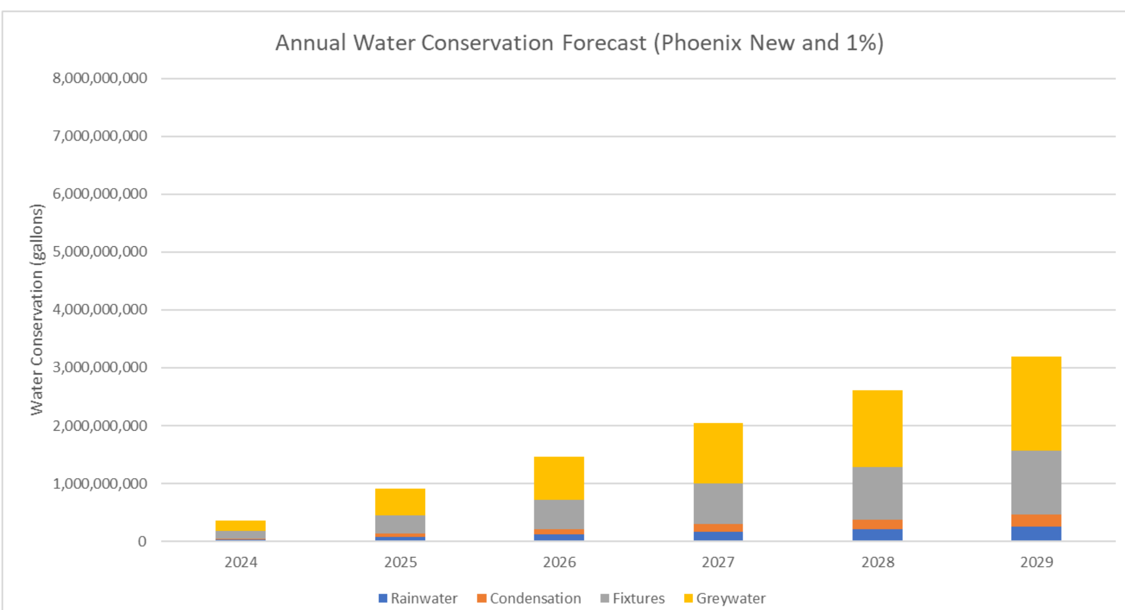


Figure XV: *Annual Water Conservation Forecast (Phoenix NH 1% Scenario)*

Importantly, if all new homes in Phoenix adopt water conservation measures along with 5 percent of old homes, significant strides can be made towards ensuring the sustainability of our water supply as demonstrated in Figure XVI. By implementing adaptive strategies that leverage both natural processes and human interventions, Phoenix can effectively manage its water resources and ensure long-term sustainability for future generations.

Consequently, policymakers and water management authorities in Phoenix are urged to closely monitor these trends and devise strategies to encourage water-saving practices across both new and existing properties, ensuring the sustainable stewardship of this vital resource for future generations.

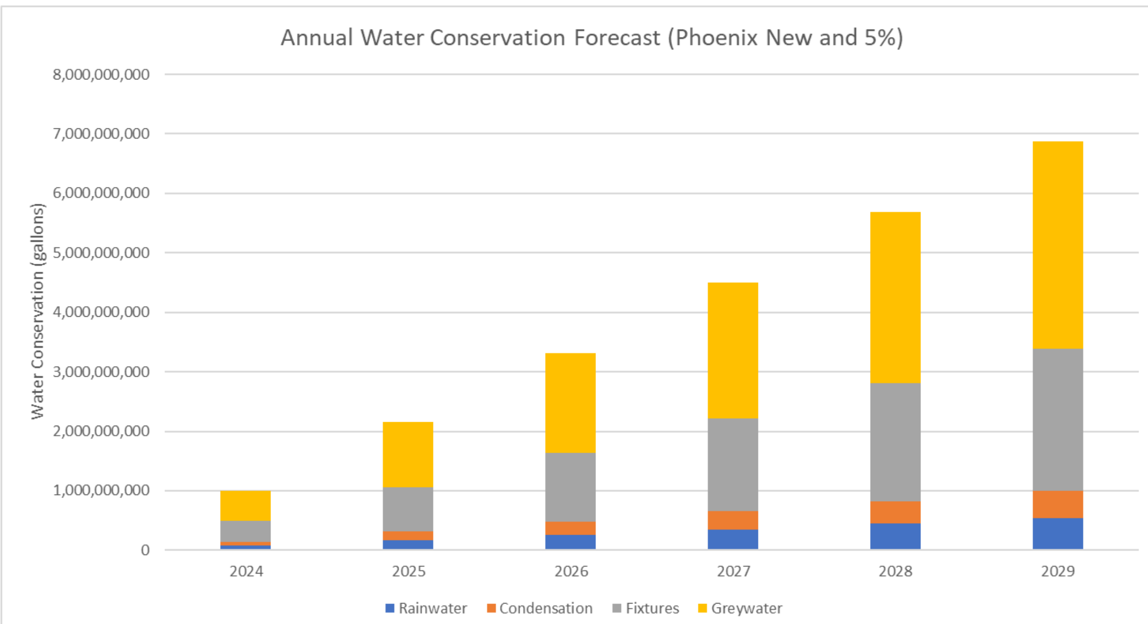


Figure XVI: *Annual Water Conservation Forecast (Phoenix NH5% Scenario)*

Table 39 presents the annual aggregate water conservation amounts across all single-family homes in Phoenix assuming every one of them adopts the provisions. These numbers provide the potential savings for the existing homes. The potential for water conservation within existing homes presents a promising outlook, with various avenues contributing to significant savings. Rainfall harvesting offers a substantial contribution of 1.25 billion gallons. As expected, in the case of Phoenix this amount is significantly lower than what is projected for the City of Houston. With condensation, the estimated potential savings amount to 1.07 billion for Phoenix. The potential water conservation from efficient fixtures is substantial, estimated at 5.60 billion gallons. This includes the adoption of low-flow toilets, faucets, and other water-efficient devices, which collectively reduce water usage while maintaining functionality. The potential water conservation from other grey water sources is significant, estimated at 8.14 billion gallons annually. Combining the conservation potential of rainwater harvesting, condensation capture, efficient fixtures, and other grey water sources, the annual aggregate water conservation for existing homes amounts to an impressive 16.08 billion gallons. Implementing water-saving practices and technologies across these various sources presents a tangible opportunity to achieve this significant conservation goal, contributing to the sustainable management of water resources.

Potential Rainfall Harvest	1.25 billion
Condensation	1.07 billion
Fixtures (Potable)	5.60 billion
Other Grey Water Harvested	8.14 billion
Total	**16.08 billion**

Table 39: Annual Potential Aggregate Water Conservation (gallons - Existing Homes)

Aggregate water conservation amounts across all scenarios over a 6-year period are summarized in Table 40. In the NH scenario, approximately 7.3 billion gallons of water are conserved over a 6-year period, reflecting the significant contribution of water-efficient practices in newly constructed homes. Moving forward, incorporating renovations in existing homes alongside new constructions yields promising results, with scenarios like NH1% conserving around 10.58 billion gallons and the most impactful NH5% saving approximately 23.55 billion gallons. These findings underscore the critical role of both new construction and renovation efforts in achieving overarching water conservation goals.

As shown in Table 40, with a rainwater and condensation conservation system a one-time investment of $1610.57 results in 1000 gallons savings every year. Hence, assuming a typical mortgage term of 30 years, conserving 1000 gallons yields a cost of $53.69 per year in that timeframe. These values are $210.90 and $7.03 for fixture-base systems and $460.94 and $15.36 for grey water harvesting. While these last two categories are comparable to the case of Houston in terms of cost, preserving a gallon of water for between 1 and 2 cents, the first two categories require substantially more investment in Phoenix for the same return. According to these results, provisions pertaining to rainwater harvesting and condensation harvesting may not be economically justified for Phoenix.

New Homes Only (NH)	7.3 billion
New Homes and 1% of Existing Homes Renovated (NH1%)	10.58 billion
New Homes and 5% of Existing Homes Renovated (NH5%)	23.55 billion
One Time Cost of Conserving 1000 gallon per year (Rain and Cond)	$1610.57
One Time Cost of Conserving 1000 gallon per year (Fixtures)	$210.90
One Time Cost of Conserving 1000 gallon per year (Grey Water Harvest)	$460.94

Table 40: Aggregate Water Conservation (gallons - New and Existing Homes over 6 Years)

7.3 Las Vegas Scaled-up Water Conservation Analysis

Figure XVII illustrates the annual water conservation forecast for Las Vegas spanning from 2024 to 2029. NH scenario starts at approximately 52 million gallons in 2024 and sharply rises to over 500 million gallons by 2029. The 6-year total reaches 1.7 billion gallons. The NH1% line begins at a similar point as the blue line but reaches almost 800 million gallons by 2029 with a total conservation of 2.5 billion gallons over 6 years. Lastly, NH5% line starts at over 250 million gallons and reaches 1.7 billion gallons in water conservation for the same forecast timeline, signifying the added benefits brought on by the existing house stock joining in on this effort. Under this scenario 6-year savings sum up to 5.8 billion gallons. In conclusion, Las Vegas anticipates a positive trend in water conservation, underscoring the importance of sustainable practices in managing this precious resource.

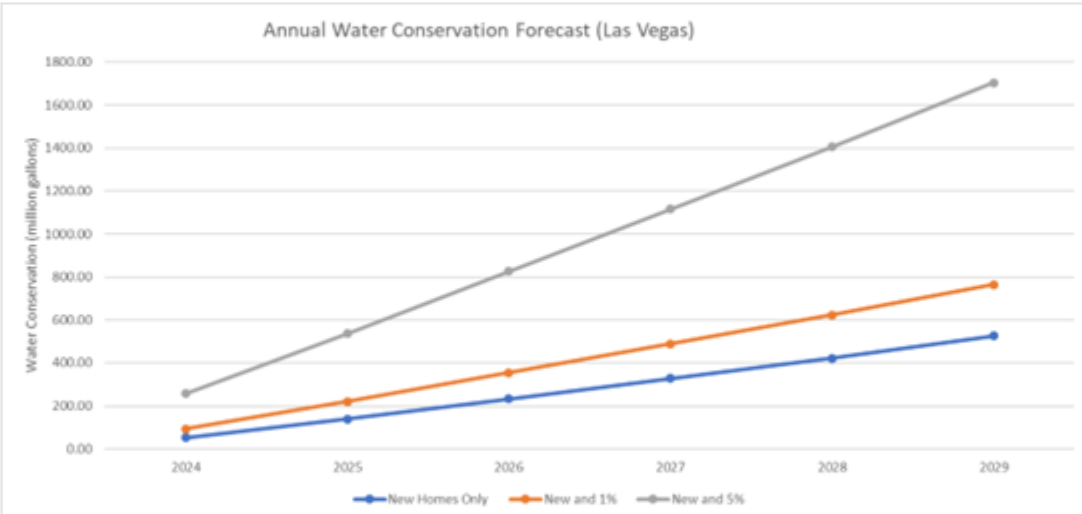


Figure XVII: *Las Vegas Scaled-up Water Conservation Analysis*

Again, it is apparent from Figure XVIII that due to this city's location in the arid Mojave Desert, rainwater harvesting and condensation water recovery are not the most impactful water conservation provisions. Meanwhile, the water efficient fixture-related conservation efforts and grey water harvesting for treatment and reuse emerge as major source of conservation for Las Vegas. Condensation water and rainwater harvesting, although not as impactful, can further contribute to preservation of water resources. These intertwined trends underscore the diverse strategies and evolving dynamics within water conservation, emphasizing the importance of adaptive approaches to ensure sustainable water management for the future. Notably, if all new homes in Las Vegas adopt water conservation measures along with just 1 percent of old homes, significant strides can be made towards ensuring the sustainability of this city's water supply.

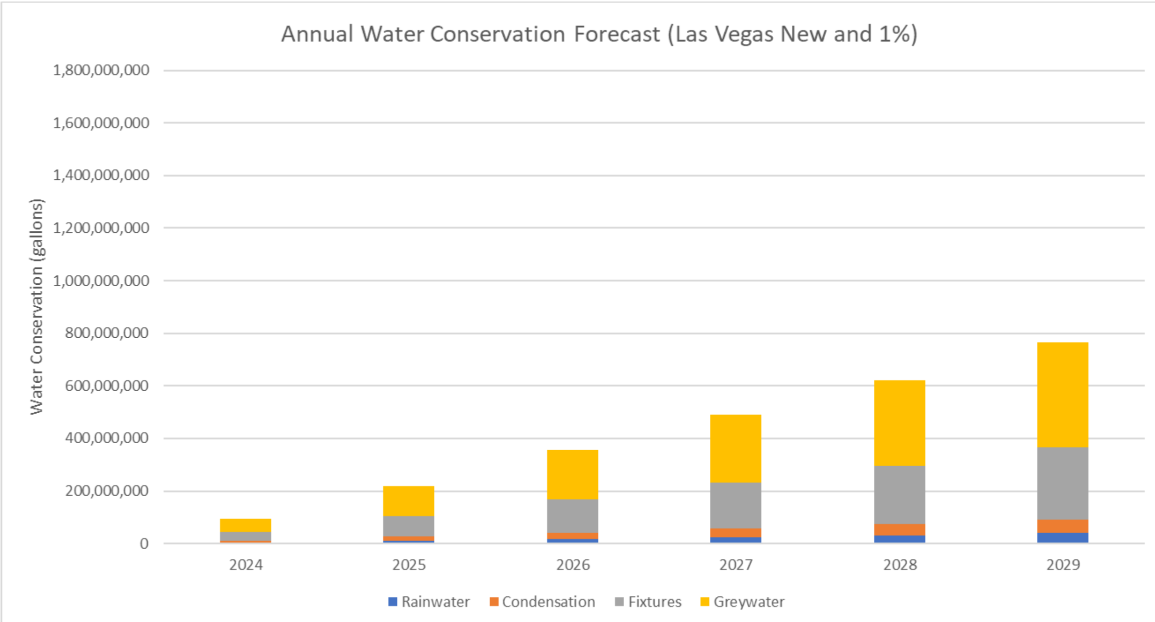


Figure XVIII: *Annual Water Conservation Forecast (Las Vegas NH1% Scenario)*

Figure XIX provides a comprehensive overview of projected water conservation efforts from 2024 to 2029 under the NH5% scenario, showcasing contributions from four distinct categories. Rainwater collection, depicted by the blue bar, and condensation capture, represented by the orange bar, demonstrate consistent contributions throughout the years. Meanwhile, the gray bar symbolizing water-saving fixtures and appliances exhibits steady and relatively larger contributions to overall conservation. Furthermore, it's the yellow bar representing grey water harvesting that stands out, showing the most significant conservation outcomes compared to the other three provisions. These key observations highlight the importance of encouraging the adoption of grey water systems coupled with promoting the installation of water-saving fixtures which can have a substantial impact on water conservation efforts. While continued investment in rainwater harvesting and condensation capture can be crucial for additional long term conservation efforts, sustaining these methods' contributions to overall conservation should be evaluated based on more detailed analysis including a cost benefit analysis. These insights have significant policy implications, emphasizing the need for comprehensive strategies to promote and support various water conservation initiatives to ensure sustainable water management for the future. Notably, if all new homes in Las Vegas adopt water conservation measures along with 5 percent of old homes, significant strides can be made towards ensuring the sustainability of our water supply.

In conclusion, Las Vegas anticipates a positive trend in water conservation, underscoring the importance of sustainable practices in managing this precious resource.

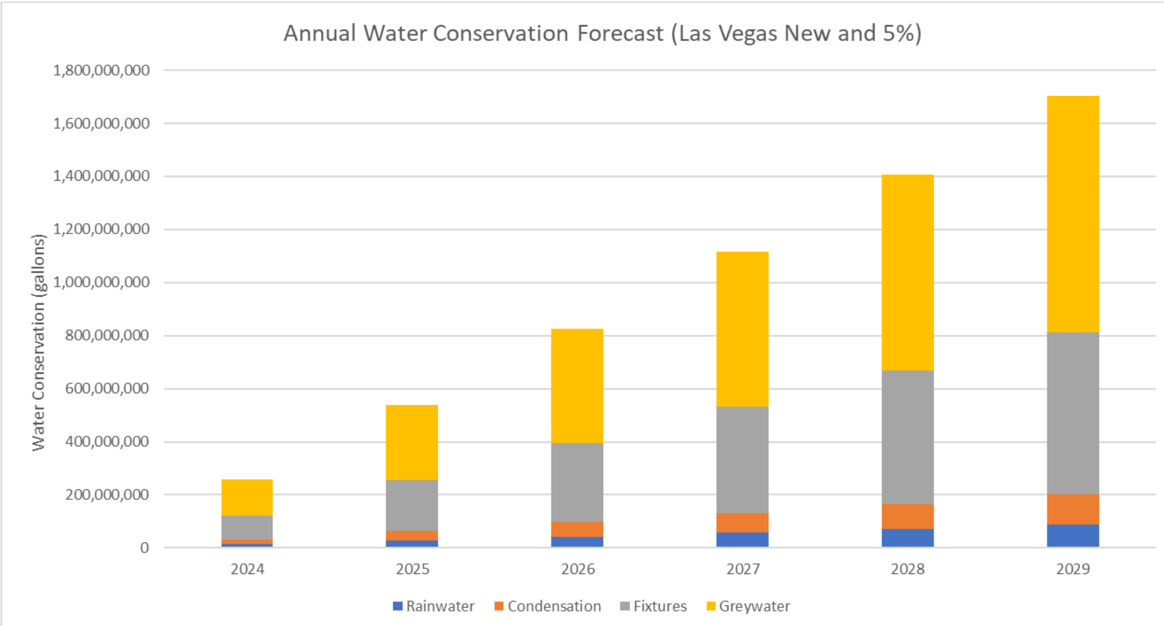


Figure XIX: *Annual Water Conservation Forecast (Las Vegas NH5% Scenario)*

Table 41 summarizes the annual aggregate water conservation amounts across all single-family homes in Las Vegas assuming every one of them adopts the studied IWCCP provisions. These numbers provide potential savings for the existing homes. The potential for water conservation within existing homes presents a promising outlook, with various avenues contributing to significant savings. Rainfall harvesting offers a contribution of 210 million gallons. As expected, in the case of Las Vegas this amount is also significantly lower than what is projected for the City of Houston. With condensation, the estimated potential savings amount to 270 million which is also significantly lower than both Houston and Phoenix. The potential water conservation from efficient fixtures is substantial, estimated at 1.47 billion gallons. The potential water conservation from other grey water sources is estimated at 2.14 billion gallons annually. Combining the conservation potential of rainwater harvesting, condensation capture, efficient fixtures, and other grey water sources, the annual aggregate water conservation for existing homes amounts to 4.09 billion gallons. Implementing water-saving practices and technologies, including rainwater harvesting, condensation capture, efficient fixtures, and grey water reuse, can help achieve significant water conservation, contributing to the sustainable management of water resources.

Potential Rainfall Harvest	0.21 billion
Condensation	0.27 billion
Fixtures (Potable)	1.47 billion
Other Grey Water Harvested	2.14 billion
Total	**4.09 billion**

Table 41: Annual Potential Aggregate Water Conservation (gallons - Existing Homes)

Forecasted water conservation efforts over the 6-year period given in Table 42 highlight the varying impacts of different scenarios. Under the NH scenario, approximately 1.7 billion gallons of water are conserved, emphasizing the importance of implementing water-saving measures in newly constructed properties. Introducing renovations in existing homes alongside new constructions increases conservation efforts, with the NH1% scenario achieving around 2.55 billion gallons of conservation. However, the most impactful approach is observed in the NH5% scenario, resulting in conserving approximately 5.84 billion gallons. These findings underscore the critical role of both new construction and renovation efforts in achieving overarching water conservation goals.

As shown in Table 42, with a rainwater and condensation conservation provisions a one-time investment of $2074.26 results in 1000 gallons savings every year. Hence, assuming a typical mortgage term of 30 years, conserving 1000 gallons yield a cost of $69.14 per year in that timeframe. These values are $212.98 and $7.10 for fixture-base systems and $464.95 and $15.50 for grey water harvesting. While these last two categories are comparable to the cases of Houston and Phoenix in terms of cost, preserving a gallon of water for between 1 and 2 cents, the first two categories require substantial investment in Las Vegas. According to these results, provisions pertaining to rainwater harvesting and condensation harvesting may not be economically viable options for Las Vegas.

New Homes Only (NH)	1.7 billion
New Homes and 1% of Existing Homes Renovated (NH1%)	2.55 billion
New Homes and 5% of Existing Homes Renovated (NH5%)	5.84 billion
One Time Cost of Conserving 1000 gallon per year (Rain and Cond)	$2074.26
One Time Cost of Conserving 1000 gallon per year (Fixtures)	$212.98
One Time Cost of Conserving 1000 gallon per year (Grey Water Harvest)	$464.95

Table 42: Aggregate Water Conservation (gallons - New and Existing Homes over 6 Years)

7.4 Des Moines Scaled-up Water Conservation Analysis

Figure XX illustrates the annual water conservation forecast for Des Moines spanning from 2024 to 2029, with the y-axis measuring water conservation in gallons per year. With only new homes adopting all the IWCCP measures, the aggregate water conservation levels are projected to increase from 44.4 million gallons in Year 1 (2024) to 475.53 million gallons by the end of Year 6 (2029) totalling 1.57 billion gallons over a 6-year period. With 1% of the existing and non-adopting homes joining this group of homes every year, the annual water conservation amount increases from 74.7 to 652.4 million gallons from Year 1 to Year 6 with a total gain of 2.2 billion gallons over a 6-year period. Under the scenario where 5% of the existing homes adapting the noted conservation provisions, the conservation amount starts at 195.6 million gallons in Year 1 and reaches 1.3 billion gallons by Year 6. This scenario results in a total water conservation of 4.6 billion gallons over a 6-year period. Overall, the forecast demonstrates the benefits of sustainable water management, emphasizing the importance of conservation efforts in ensuring a resilient and environmentally sound future.

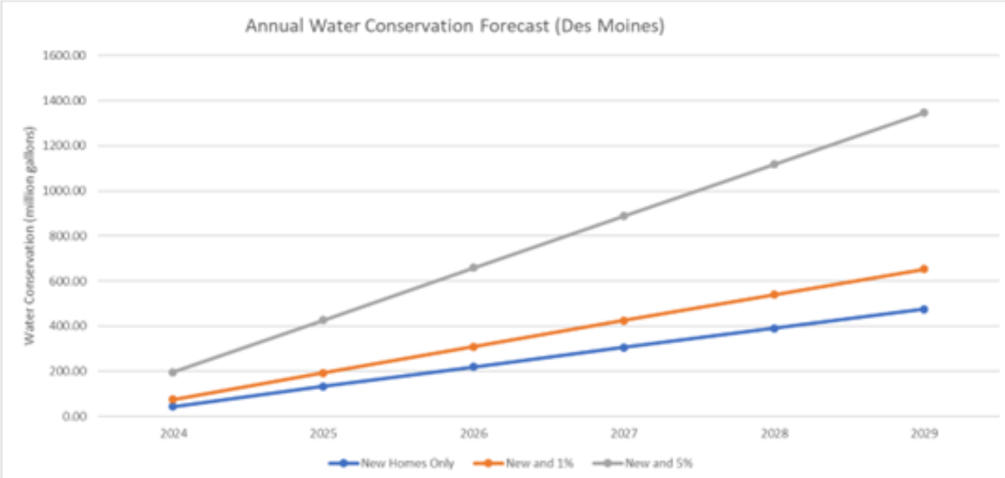


Figure XX: *Des Moines Scaled-up Water Conservation Analysis*

Figure XXI illustrates the forecasted water conservation efforts over a 6-year period, detailing contributions from different sources over time. Based on geographic location and the climate zone Des Moines is located at, it is apparent that condensation recovery provision does not deliver a noteworthy contribution for water conservation in this city. Rainwater harvesting, represented by the blue bar, water-saving fixture installations represented by the gray bar, and grey water harvesting represented by the yellow bar all exhibit consistent and proportionally significant contribution levels for water conservation in this city. These varied trends underscore the complexity of water conservation strategies, emphasizing the need for adaptive approaches in concert with detailed demand-based water balance evaluation when integrating each of these measures individually and/or in aggregation to ensure sustainable water management for the future. Notably, if all new homes in Des Moines adopt water conservation measures along with 1% of old homes, significant strides can be made towards ensuring the sustainability of our water supply.

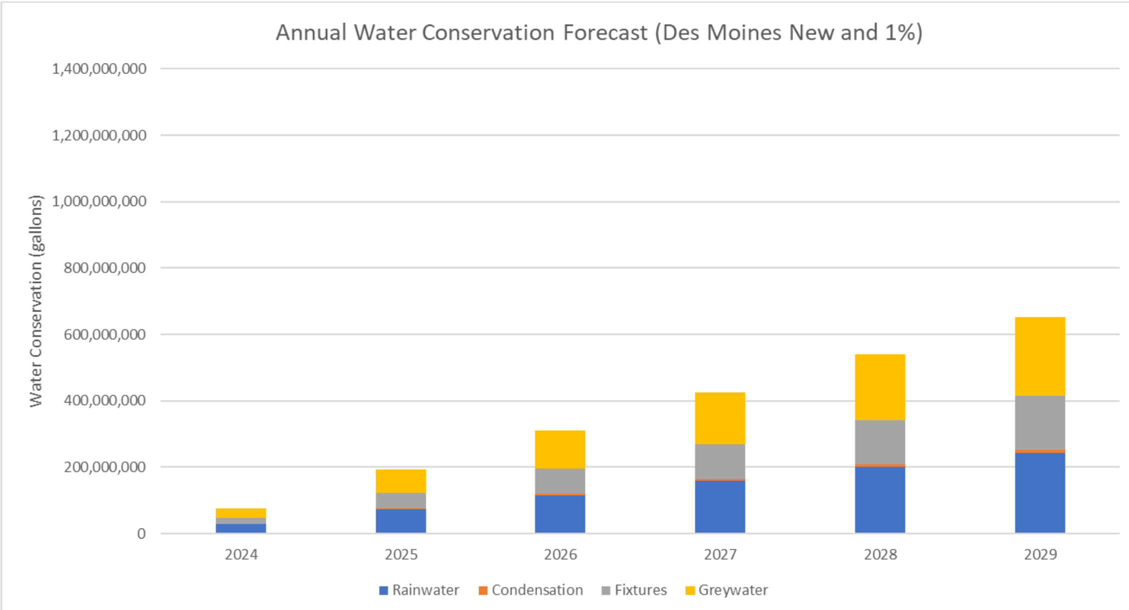


Figure XXI: *Annual Water Conservation Forecast (Des Moines New & 1%)*

Figure XXII provides a comprehensive overview of projected water conservation efforts from 2024 to 2029, showcasing contributions from four distinct categories under the NH5% scenario. These key observations highlight the importance of encouraging the adoption of grey water systems, installation of water-saving fixtures and integration of rainwater harvesting as proportionally significant conservation provisions, yielding significant water conservation outcomes. If all new homes in Des Moines adopt these water conservation measures along with 5% of old homes significant strides can be made towards ensuring the sustainability of this city's water supply. Coupling these methods based on demand vs supply dynamics can optimize water usage and ensure sustainable water management for Des Moines, building a resilient future.

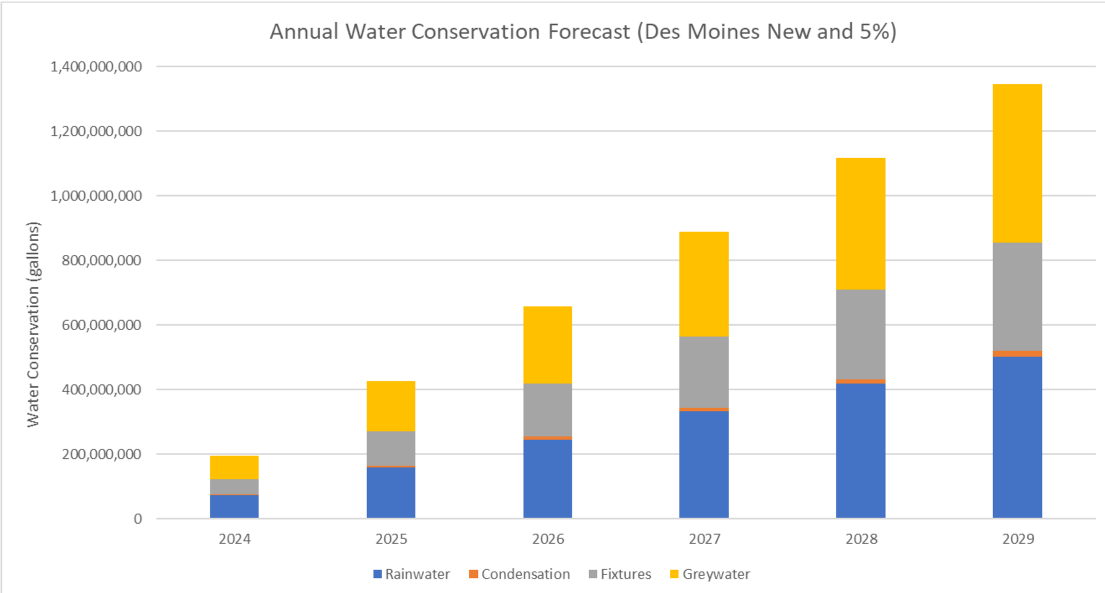


Figure XXII: *Annual Water Conservation Forecast (Des Moines New & 5%)*

Table 43 summarizes the annual aggregate water conservation amounts across all single-family homes in Des Moines assuming every one of them adopts the provisions. Rainwater harvesting offers a contribution of 1.13 billion gallons. With condensation, the estimated potential savings amount to 40 million which is significantly lower than all other three cities. The potential water conservation from efficient fixtures amounts to 750 million gallons. The potential water conservation from other grey water sources is estimated at 1.1 billion gallons annually. Combining the conservation potential of rainfall harvesting, condensation capture, efficient fixtures, and other grey water sources, the annual aggregate water conservation for existing homes amounts to 3.02 billion gallons.

Potential Rainfall Harvest	1.13 billion
Condensation	0.04 billion
Fixtures (Potable)	0.75 billion
Other Grey Water Harvested	1.10 billion
Total	**3.02 billion**

Table 43: Annual Potential Aggregate Water Conservation (gallons - Existing Homes)

Table 44 describes the conservation amounts over a six-year period in all three scenarios. Under the NH scenario, approximately 1.57 billion gallons of water are conserved, emphasizing the importance of implementing water-saving measures in newly constructed properties. Introducing renovations in existing homes alongside new constructions increases conservation efforts, with the NH1% scenario achieving around 2.19 billion gallons of conservation. As expected, the most impactful approach is observed in the NH5% scenario, resulting in conserving approximately 4.63 billion gallons. These findings underscore the critical role of both new construction and renovation efforts in achieving overarching water conservation goals.

As shown in Table 44, with a rainwater and condensation conservation provisions a one-time investment of $483.14 results in 1000 gallons savings every year. Hence, assuming a typical mortgage term of 30 years, conserving 1000 gallons yield a cost of $16.10 in that timeframe. These values are $236.57 and $7.89 for fixture-base systems and $510.42 and $17.01 for grey water harvesting. The last two categories are comparable to all other cases. On the other hand, while the investments in first two categories are high compared to Houston, they are significantly below Phoenix and Las Vegas.

New Homes Only (NH)	1.57 billion
New Homes and 1% of Existing Homes Renovated (NH1%)	2.19 billion
New Homes and 5% of Existing Homes Renovated (NH5%)	4.63 billion
One Time Cost of Conserving 1000 gallon per year (Rain and Cond)	$483.14
One Time Cost of Conserving 1000 gallon per year (Fixtures)	$236.57
One Time Cost of Conserving 1000 gallon per year (Grey Water Harvest)	$510.42

Table 44: Aggregate Water Conservation (gallons - New and Existing Homes over 6 Years)

7.5 Synthesis of Analysis across the four cities based on geographic and climatological differences.

Across Phoenix and Las Vegas, characterized by arid climates with limited rainfall, water-saving fixture installation and grey water harvesting systems are pivotal for water conservation. Rainwater harvesting allows for the capture and storage of precious rainwater during infrequent rainfall events, providing a supplementary water source for landscaping and other non-potable uses. Grey water systems recycle wastewater from sinks, showers, and laundry for irrigation purposes, further reducing reliance on scarce freshwater supplies. Combining these provisions in these arid regions can maximize water conservation efforts by leveraging natural precipitation and recycling wastewater, ensuring a more sustainable water supply.

Conversely, in Des Moines and Houston, where rainfall is more abundant but still subject to seasonal variability, optimizing water usage through efficient fixture installation and grey water recycling becomes paramount. Efficient fixtures such as low-flow toilets and faucets can significantly reduce water consumption without compromising functionality. Additionally, grey water recycling systems can divert wastewater from showers and sinks to be treated and reused for irrigation or toilet flushing, minimizing the strain on municipal water supplies. By focusing on these provisions, Des Moines and Houston can effectively manage their water resources while adapting to fluctuating rainfall patterns and ensuring resilience in the face of future water challenges.

From centralized utility infrastructure perspective, in aggregating different provisions based on the unique characteristics of each city, municipalities can achieve the most optimized and cost-effective water conservation outcomes. By tailoring strategies to suit local climatic conditions and water availability, cities can maximize water savings while minimizing the financial and environmental costs associated with water management.

Rainwater harvesting, condensation harvesting, water-efficient plumbing fixtures, and grey water collection and treatment for reuse can all significantly reduce the burden on potable water utility plants, especially in regions facing water scarcity and population growth. While reclaimed water is typically cheaper due to lower treatment costs and potentially lower user rates, initial infrastructure investment for a separate reclaimed water system can sometimes outweigh the immediate cost savings. Water scarcity and local regulations can influence pricing strategies for both reclaimed and potable water. The cost-effectiveness of reclaimed water depends on the intended use. It's most suitable for applications like irrigation and toilet flushing where potable water quality isn't necessary.

Decentralized strategic initiatives and planning can help keep the cost of potable water low against increasing demand in arid regions facing population growth and water scarcity by reducing demand for potable water while also producing noteworthy benefits for the regional utility plants. With less water being drawn from potable sources, treatment plants require less processing and lower energy consumption, leading to lower operational costs. Furthermore, this results in reduced strain on infrastructure; decreased demand on the potable water system reduces pressure on pipes and treatment plants, potentially delaying the need for expensive upgrades. The ultimate collective outcome is improved water security; these practices promote water independence and resilience, especially during droughts or periods of peak demand.

From environmental and cost savings perspectives, these initiatives also produce reduced reliance on freshwater sources, helps conserve natural resources and groundwater levels, while at individual user level, rainwater and condensation harvesting, grey water systems and use of water efficient fixtures can lead to lower water bills by reducing dependence on potable water.

Implementation and Recommendation Considerations:

- **Initial Investment:** Although cost-saving in the long run for the life of the building, these initiatives require upfront investment for installation.
- **Regulations:** Local regulations may exist regarding rainwater and condensation harvesting and grey water collection, treatment and re-use. It's crucial to check local ordinances before implementing these systems.
- **Climate Suitability:** Rainwater and condensation harvesting is most effective in regions with predictable rainfall and relative humidity patterns.

The data underscores the importance of adopting a multifaceted approach to water conservation, encompassing both new construction practices and renovation efforts in existing homes. Policymakers are encouraged to promote cost-effective methods such as water-saving fixtures and grey water harvesting to incentivize widespread adoption. Additionally, public awareness campaigns play a vital role in encouraging responsible water usage practices across all homes, fostering a culture of conservation and sustainability within communities. These recommendations pave the way for collaborative efforts towards achieving sustainable water management and ensuring the availability of this vital resource for future generations.

In summary, while each water conservation provision considered may have some limitations, their combined effect can significantly reduce the burden on potable water utility plants. By promoting these practices, communities can become more water-secure and sustainable, especially in the face of increasing water scarcity. By implementing a combination of these strategies, arid regions can manage water resources efficiently, reduce demand, and keep the cost of potable water affordable for a growing population. It's important to note that the most effective approach will depend on the specific circumstances of each region. This approach fosters a more sustainable and resilient water infrastructure that can meet the needs of present and future generations.

8.0 Conclusions

In the pursuit of a more sustainable future, the imperative to conserve water resources has never been more pressing. As our planet grapples with the consequences of climate change and population growth, the need to adopt innovative solutions for water management has become paramount. The detailed proposal presented here offers a comprehensive roadmap for addressing this challenge head-on, harnessing the power of technology, policy, and community engagement to pave the way for a more water-resilient world.

At the heart of this study lies a recognition of the urgent need for action. Internationally, code officials and designers have long recognized the need for a modern, up-to-date code governing the impact of buildings and structures on the environment. The IWCCP serves as a beacon of hope in this regard. Its code provisions are designed to promote water conservation through safe and sustainable construction practices, offering a clear and specific regulatory framework for achieving this goal.

The scope of this project is ambitious yet necessary. By conducting a scientifically based study across select cities and states, including Houston, Texas, Phoenix, Arizona, Des Moines, Iowa and Las Vegas, Nevada, the project aims to demonstrate the benefits of adopting the IWCCP across single family and low-rise multi-family residential occupancies. Through numerical modelling and systems engineering approaches, this study explores a variety of water conservation provisions detailed in the referenced codes, strategically aligning them with regional priorities and resource management strategies.

The exploration of various supplemental water sources and use of water efficient plumbing fixtures in the residential building sector underscores the breadth of opportunities available for reduction in potable water demand and path forward for sustainable water management. Grey water reuse systems, for example, offer a means of harnessing untreated wastewater from household sources for non-potable purposes like irrigation and toilet flushing. By capturing and treating water from showers and laundry, grey water systems provide a sustainable alternative to traditional water sources, reducing strain on municipal supplies and promoting water security.

Similarly, condensation collection presents an opportunity to repurpose water traditionally discarded as waste. By capturing condensation from HVAC systems, households can tap into a valuable water source for non-potable applications. This approach is particularly relevant in more humid regions with high cooling demands, where condensation production can be substantial. Through efficient collection and treatment methods, condensation collection systems represent a significant step towards sustainable water management.

Rainwater collection systems further exemplify the potential for leveraging natural resources to meet water needs. By gathering and treating rainwater from impervious roofing surfaces, these systems reduce reliance on potable water for tasks like irrigation, thereby promoting water conservation and environmental sustainability. The implementation of rainwater collection systems not only conserves water but also mitigates stormwater runoff, alleviating pressure on municipal drainage systems and reducing the risk of urban flooding.

Moreover, reclaimed water systems offer a groundbreaking solution for repurposing treated wastewater to meet non-potable water needs. By treating wastewater to meet public health standards, reclaimed water systems provide a sustainable water source for irrigation, industrial processes, and other non-potable applications. This approach not only conserves water but also reduces the environmental impact of wastewater discharge, contributing to overall water quality and ecosystem health.

The comparison between baseline code minimums and proposed water conservation provisions reveals the tangible benefits of embracing sustainable practices. In cities like Houston, Texas and Phoenix, Arizona, the potential for significant reductions in municipal water usage for non-potable purposes is not just theoretical but within reach. Even in regions with moderate reductions in municipal water usage, such as Las Vegas, Nevada and Des Moines, Iowa, the proposed provisions offer tangible opportunities for enhancing sustainability and reducing environmental impact.

In conclusion, the study presented herein represents a comprehensive framework for advancing water conservation in residential settings. By embracing innovative approaches and leveraging natural resources, we can achieve significant reductions in water usage, promote environmental stewardship, and ensure a sustainable future for generations to come. Overall, there is significant potential in embracing these opportunities and paving the way towards a more water-resilient world.

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