The Untapped Potential of California's Urban Water Supply: Water Efficiency, Water Reuse, and Stormwater Capture: **Appendix A. Methods**

This appendix provides detailed methods for estimating the urban water efficiency, water reuse, and stormwater capture potentials.

Urban Water Efficiency Potential

This analysis focuses on water efficiency opportunities in homes, businesses, institutions, and in the water distribution system. For each, we estimated current and efficient water use, with the difference between these values representing the efficiency potential. Current water use was based on the Electronic Annual Reporting (EAR) datasets for the years 2017, 2018, and 2019 – the most recent years for which data were available. The EAR is an annual survey of public water systems that collect water-system information, including water use by sector. Prior to analysis, we removed blanks and outliers from the EAR dataset. The EAR dataset represented approximately 88% of the statewide population in 2019. We developed statewide estimates of current and efficient water use by scaling the regional estimates up using 2019 population estimates from the Department of Water Resources (DWR) for each of the state's 10 hydrologic regions.

Residential Water Use and Savings

Current indoor and outdoor residential water uses were estimated based on data provided by the State Water Board. These data contained estimates of indoor use developed using a methodology validated by DWR staff in the Indoor Residential Water Use Study (California Department of Water Resources (DWR) 2021). We subtracted indoor residential gallons per capita per day (R-GPCD) from the total R-GPCD reported in the EAR dataset to estimate outdoor R-GPCD. Indoor and outdoor R-GPCD were available for a total of 331 water suppliers across California. We did a simple average of all water suppliers within each hydrologic region to develop a single estimate of indoor and outdoor R-GPCD for each of the state's 10 hydrologic regions. We then multiplied indoor and outdoor R-GPCD for each hydrologic region by its 2019 population to estimate water use, in acre-feet.

Potential residential indoor savings were calculated as a difference between current water use and water use if all households were equipped with efficient appliances and fixtures. The low estimate of water savings was based on appliances and fixtures that meet current California standards, and the high estimate was based on leading-edge technology that is available but not yet mandated. The leading-edge technologies were based on EPA WaterSense certified devices with the lowest flow rate. For each, the efficiency standard was multiplied by estimates of the frequency of use (e.g., number of flushes per day) to determine efficient use, in gallons per person per day. In total, we estimate that average indoor water use would be 35 gpcd in a home equipped with appliances and fixtures that meet current California standards, and 25 gpcd in a home equipped with leading-edge technologies (Table 1).

Table 1. Water flow rates and frequency of use for residential appliances and fixtures with California standards and leading-edge technology, and resulting residential indoor water use (in gallons per person per day)

Indoor End Use	Water Flow Rates			Frequency of Use	Indoor Water Usage (gpcd)	
	California standards	Leading Edge Technologies	Units		California standards	Leading Edge Technologies
Toilet (single-flush, tank-type)	1.28	0.79	gallons per flush	4.76 flushes per person per day	6.09	3.76
Clothes washer (min. is front-loading)	21.15	13.72	gallons per load	0.35 loads per person per day	6.77	4.39
Showerhead	1.8	1	gallons per minute	5.8 mins per person per day	10.49	5.83
Faucet	11.1	11.1	gallons per person per day	N/A	11.10	11.10
Dishwasher (standard)	5	1.95	gallons per cycle	0.1 cycles per person per day	0.50	0.20
TOTAL	-	-	-	-	35	25

Notes: DeOreo et al. 2011 found that faucet water use was 11.1 gallons per person per day. We assumed that faucet water usage was determined by volume rather than by the flow rate of the device, resulting in a conservative estimate of water savings from faucets. Clothes washer values are calculated for front-loading washers.

Source: The frequency of use for each end use was based on DeOreo et al. 2011. California standards data are based on the California Plumbing Code. Leading edge technology information are based on EPA WaterSense.

To estimate potential outdoor water savings, we used the landscape water budget method, where plant species are classified by their water needs and assigned a “water-use factor.” The water-use factor is the ratio of the plant’s water needs to that of a well-watered grass crop, or “reference evapotranspiration,” and varies with location, weather, and other factors (Costello, Matheny, and Jones 2000). High water demand plants, such as cool-season grass or vegetable gardens, have water-use factors of 1 or more, while low water-use plants may have factors as low as 0.1 and require little or no supplemental irrigation. Recent studies have found that residential landscapes in California have an average water-use factor of around 0.8 (DWR 2021). For the low estimate of water savings, we assumed urban landscapes have a water-use factor of 0.55, which is the maximum level allowed for new residential developments exceeding 500 square feet under the Model Water Efficient Landscape Ordinance (MWELO). For the high estimate, we assumed complete conversion to climate-appropriate vegetation and efficient drip irrigation, equivalent to a water-use factor of 0.37.

Commercial, Industrial, and Institutional (CII) Water Use and Savings

The EAR contains three major categories that, in aggregate, represent CII water use: (1) commercial and institutional; (2) industrial; and (3) large landscapes. While “large landscapes” represent outdoor use, the “commercial and industrial” and the “institutional” (hereafter referred to as CII) water-use categories are a combination of indoor and outdoor uses. Based on East Bay Municipal Utility District (EBMUD) (2008), we assumed that 80% of the reported use for the CII water-use categories represents indoor use, and the remaining 20% was outdoor use. To scale values to encompass statewide population, we calculated the ratio between hydrologic region population from DWR for 2019 and population estimates from the EAR for each hydrologic region. We multiplied this ratio by our water use values for CII indoor and outdoor. Hydrologic region estimates were then aggregated to obtain a statewide estimate.

There are many ways that the CII sector can reduce indoor water use, reflecting the diversity of ways in which water is used inside the building. Some of these are like residential water efficiency measures, such as installing efficient toilets and urinals, while others are customized for specific end uses. However, limited data were available on water uses within the CII sector and potential water savings. Based on the available literature, including policy documents, case studies, and water audits, we estimated that CII water savings ranged from 30% to 50% (Gleick et al. 2003). Outdoor water savings for the CII sector were based on the landscape water budget method. Here, we assumed that current water use is at a water-use factor of 0.89 (DWR 2021). For the low estimate of water savings, we assumed a water-use factor of 0.45 for CII landscapes, which is the maximum level allowed for new CII developments exceeding 500 square feet or rehabilitated landscape projects with an area equal to or greater than 2,500 sq. ft under the MWELO. For the high estimate, we assumed complete conversion to climate-appropriate vegetation and efficient drip irrigation, equivalent to a water-use factor of 0.37. Special landscape areas, as designated by MWELO, are certain areas that are allowed more water use than others and are subject to a water use factor of 1.0. These include areas irrigated using recycled water, public recreational areas, etc. Based on the literature, we assumed that

13% of CII outdoor area is special landscape area (Lindsey Stuvick, MNWD, personal communication, November 2, 2021; Waterfluence LLC 2021) and has a water-use factor of 1.0 in all estimates.

Non-Revenue Water and Water Savings

Non-revenue water is water that has been produced but is "lost" before it reaches the customer and does not generate revenue for the utility. These losses can be real losses (e.g., physical losses through leaks), apparent losses (e.g., meter inaccuracies, billing errors, or theft), and authorized unbilled uses (e.g., a fire department taking water from a hydrant).

To estimate non-revenue water, we first determined real water losses for each hydrologic region using the State Water Board's clean dataset on water loss performance standards (State Water Resource Control Board, n.d.). Second, we estimated the fraction of non-revenue water that represents real water losses for each hydrologic region based on data from supplier-reported Water Audit information (California Department of Water Resources (DWR), n.d.). We then divided the reported real losses by this fraction to estimate non-revenue water for each hydrologic region.

Senate Bill 555, passed by the California legislature in 2015, requires water suppliers to comply with individual volumetric water loss standards by 2028. These standards, based on data from 2017 to 2020, were developed using an economic model for leak detection and repair actions (State Water Resources Control Board 2020). We obtained data on reported real water losses and individual performance standards for each urban water supplier from the State Water Board's Water Loss Control website (State Water Resource Control Board, n.d.). A moderate and high-efficiency estimate was based on the water loss performance standards developed by the State Water Board. The moderate efficiency estimate was developed keeping standards as prescribed, while the "high-efficiency estimate" was developed by constraining all standards that are higher than current real loss to the current value. These current and efficient estimates were scaled to statewide population. We then estimated potential water savings for each water supplier based on the difference between current water losses and the performance standard. Water savings were summed by hydrologic region and statewide.

Water Reuse Potential

Key Sources of Data

California State Water Resources Control Board Volumetric Annual Reporting Data

Description: All facilities treating and disposing of municipal wastewater and holding a National Pollutant Discharge Elimination System (NPDES) or Waste Discharge Requirement (WDR) permit. Reporting data is comprised of four sub-datasets: facility information, influent, effluent, and reuse.

How These Data Were Used: Foundational data in assessing the quantity of effluent potentially available for reuse.

Time: Reported annually with monthly, facility-level data included. Reporting began in 2019 with the most recent 2020 data used in this analysis.

Key Variables Used in This Analysis:

- Facility information (latitude/longitude, facility descriptors);
- Effluent (monthly volumes, discharge locations, instream flow requirements); and
- Reuse (reuse volume, reuse category)

California Department of Water Resources Hydrologic Regions

Description: Vector format file (shapefile) mapping boundaries of hydrologic regions.

How These Data Were Used: GIS was used to overlay these data with processed SWRCB volumetric annual reporting data to estimate the quantities of effluent potentially available for reuse by region.

Summary of Analytical Approach

Part 1: Data Cleaning and Pre-Processing

All datasets (facility information, influent, effluent, reuse) were imported into Microsoft Access. 'GlobalID' was used as the common identifying ID across records. Summary queries were developed to sum the annual volume of effluent produced by each facility by discharge location (e.g., inland surface waters, marine outfalls). The summary table (effluent by facility) was then joined with facility-level information to attribute these sums with latitude/longitude and classify effluent flows by facility type:

- Wastewater treatment plant (WWTP) without recycled water production;
- WWTP producing recycled water onsite;
- WWTP supplying effluent to an offsite recycled water producer; and
- Facilities that produce only recycled water.

Facility locations were mapped using the GPS coordinates in the 'Facility Information' data. When GPS coordinates provided were missing or inaccurate, we manually assigned the facility to the correct DWR hydrologic region based on the regional numeric codes used in the NPDES/WDR permit numbers and/or internet searches for the facility location.

Part 2: Estimating the Total Portion of Flows Potentially Available for Reuse

Outputs from Part 1 were further sub-classified and summed to estimate the volume of effluent currently recycled, potentially available for reuse, not available for reuse, or unknown/discharged. Data were portioned first by facility type then discharge location to avoid double counting water produced by a WWTP then supplied to a recycled water producer.

Key factors used to classify the reuse potential of different flows of water are summarized below.

Currently Recycled Water (728,000 AFY): Effluent that is currently recycled is unavailable for future reuse. Recycled water use was also summed by Title-22 beneficial use (e.g., agricultural irrigation, seawater intrusion barrier).

Water Potentially Available for Reuse (2,057,000 AFY): Discharge location was a major factor in determining whether effluent may be available for reuse. Water discharged to all locations except inland surface waters and natural systems was assumed to be 'potentially available for reuse.' The main report discusses the tradeoffs of using water discharged to different locations in more detail. Effluent discharged to inland surface waters was assumed to be 'potentially available for reuse' if that water was not already reserved to meet state-mandated instream flow requirements.

Water Not Available for Reuse (285,000 AFY): Effluent reserved for instream flow requirements or discharged to natural systems (e.g., wildlife refuges) was assumed to not be available for reuse.

Unknown/Discharged (70,000 AFY): Some disparities were observed in the quantities of water WWTP reported discharging to recycled water producers and the quantity of water recycled water producers reported supplying. 70,000 AFY is the sum of small disparities observed across a number of (mostly) South Coast facilities. One larger reporting discrepancy (~200,000 AFY) was identified at one Bay Area facility. This difference was likely due to a reporting units error and effluent data from this wastewater facility were excluded from our analysis. However, the data from the recycled water producer receiving water from this facility appeared to be correct and is included in the totals for current recycled water production.

Part 3: Differences in Current and Potential Reuse Across Hydrologic Regions

Outputs from Parts 1 and 2 were used to sum the quantities of water in each class (e.g., currently recycled, potentially available for reuse) for each hydrologic region.

Part 4: Future Changes in the Quantity of Water Potentially Available for Reuse

We compared our estimates of the volumes of current wastewater effluent potentially available for reuse to estimates of water use under future water use efficiency scenarios and current reuse. The methods used to estimate future water use are described earlier in this appendix.

Part 5: Role of Water Quality in Assessing the Potential for Reuse

The portion of water 'potentially available for reuse' was extracted from the data and classified based on the reported levels of treatment. The seven reported treatment classes (e.g., Secondary treatment, Disinfected Secondary-2.2, Disinfected Secondary-2.23) were condensed into four high-level classes: primary, secondary, tertiary, and full advanced treatment. Disinfection is an important determinant in the types of reuse that are allowable with a given source of water. Reporting on whether water was disinfected was typically only reported by facilities already supplying recycled water and using the Title-22 classification system in their reporting.

Part 7: Analysis Validation and Checks

As a general data check, we also compared estimates of current indoor water use (EAR data) with current volumes of wastewater effluent and current reuse (VAR data). Current wastewater production was within 10% (+/-) of current indoor water use in six of 10 hydrologic regions (Figure 1). In the San Francisco Bay Area, current wastewater production was 14% higher than indoor urban water use. In the remaining three regions (Colorado River, South Lahontan, and Tulare Lake), current wastewater production was lower than current indoor water use. These differences can be due to:

- Not all customers of water systems are connected to centralized wastewater systems (and vice versa);
- In rural and peri-urban areas, septic and other on-site systems are common and not captured in the Volumetric Annual Reporting data;
- The water supplier for some customers located on the periphery of a hydrologic region may be located in a different hydrologic region than their wastewater discharge point (e.g., portions of the Bay Area);
- There were some differences noted between the volumes of effluent supplied to recycled water producers and the volumes of water that recycled water producers reported supplying for reuse;
- Portions of the City of San Francisco are served by a combined sewer system that receives both wastewater and stormwater. During low-flow precipitation events,

wastewater treatment plants receive and treat both wastewater and stormwater. During high-flow precipitation events, flows can exceed the capacity of the sewer system and overflow a portion of the combined effluent into the Bay or ocean prior to treatment; and

- Differences/inconsistencies in how existing recycled water use is captured in EAR water use data.

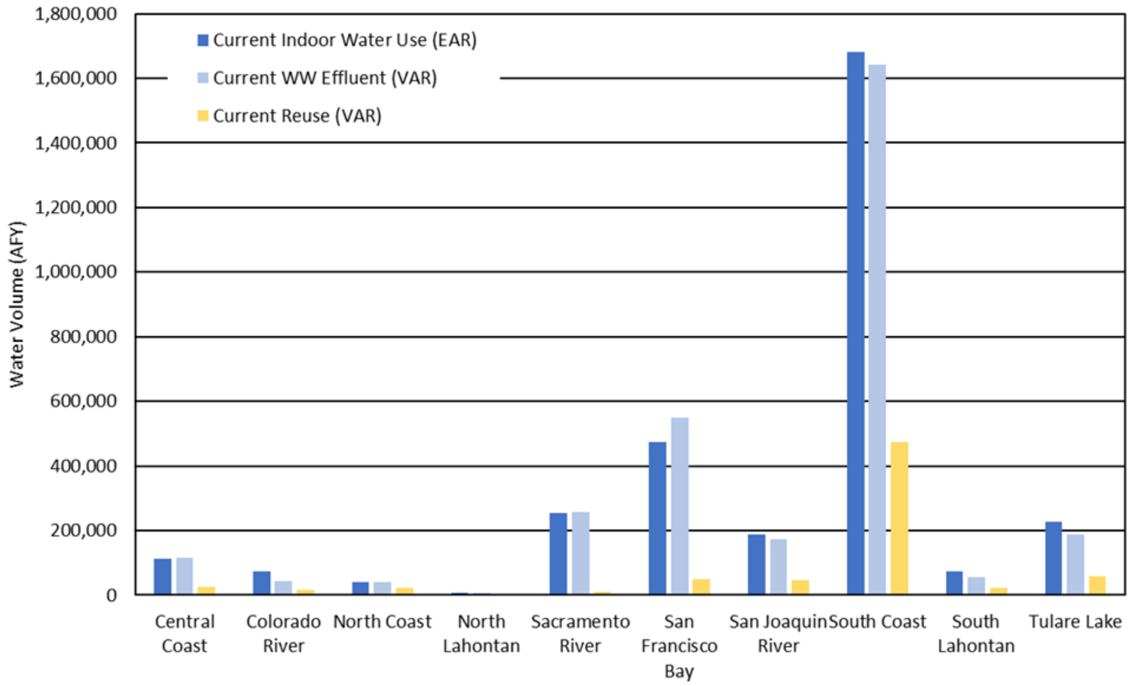

Figure 1. Comparison of current indoor water use, wastewater effluent, and reuse.

Stormwater Capture Potential

The potential volume of urban stormwater available for capture, infiltration/recharge, and reuse were estimated for a "low," "medium," and "high" precipitation year (January 1st-December 31st) in California. Historical annual precipitation data for 2010-2020 (PRISM Climate Group 2021) were used to identify those years within the range that had the lowest (i.e., 2013), medium (i.e., 2011), and highest (i.e., 2010) total measured precipitation. Gridded (raster) data of total depth of annual rainfall (mm) were obtained for each representative year used in the analysis.

In a geographic information system,[1] for each year, we used the gridded precipitation data along with gridded impervious area data and a runoff coefficient to estimate runoff volume for all urban areas in the state (Equation 1). This provided a high-end estimate of potential volume

[1] ArcGIS Pro v2.8.1

for capture regardless of whether water demand or storage options were immediately available.

Equation 1.

*Precipitation (mm) * Impervious Area (m) * Runoff Coefficient = Runoff Volume (m^3)*

Urban areas were designated based on the 2010 US Census Bureau's "Urban and Rural" classification using a shapefile (U.S. Census Bureau 2010). Impervious area was based on 2016 NLCD impervious surfaces as a percentage of developed surface in 30 m x 30 m grid cells. The runoff coefficient was calculated for every grid cell using an equation by Schueler (1987), [2] following the approach used in Garrison et al. (2014).

After the high-end estimate was calculated, aquifer locations were used to further constrain where the available runoff would be able to infiltrate the subsurface and recharge groundwater. Aquifer locations were based on the California Department of Water Resources Sustainable Groundwater Management Act dataset (DWR 2020). Aquifers with at least one public supply well (State Water Resource Control Board, 2016) were included.

This analysis makes several simplifying assumptions that may not be valid everywhere. For example, it assumes that every urban area in the state, inland and coastal, has at least some potential for stormwater capture and reuse. Some local jurisdictions, however, have restrictions on stormwater capture based on instream-flow regulations and other rules. The actual stormwater capture potential in a specific location depends on a variety of factors, including but not limited to:

- Local laws and regulations related to instream flows and water rights of downstream communities;
- Land area suitable for larger recharge projects;
- Connectivity between runoff generated and recharge zones;
- Infiltration capacity of exposed soils in potential recharge zones; and
- Water quality and other treatment considerations.

Additionally, we were not able to account for the total volume of urban stormwater already being captured and reused in the state. There is currently no centralized data source for identifying and quantifying urban stormwater capture and use for water supply. The Department of Water Resources (DWR) created a list of statewide urban and nonurban stormwater capture projects in 2018, however, this is not a complete picture of all stormwater capture in the state as it only accounts for projects that were at least partially funded by state

[2] Page 1.11: Rv (runoff coefficient) = 0.05 + 0.009(I); where I = the percent of site imperviousness

proposition funds (DWR 2018). Effort is underway at the State Water Board to quantify stormwater capture in California, but this work is not yet complete.

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