A WHITE PAPER

The Potential for Urban Stormwater as a Water Supply

November 21, 2016

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CALIFORNIA URBAN WATER AGENCIES

SECTION 1

Executive Summary

Interest in the potential use of urban stormwater as a water supply in California is growing, and new funding sources to better manage and develop urban stormwater as a resource are being explored. This white paper aims to inform the ongoing statewide dialogue by characterizing current urban stormwater uses and the opportunities and challenges associated with its increased capture to supplement California's water supply.

Introduction

CUWA agencies are committed to leveraging urban stormwater as a water supply resource where feasible and cost-effective.

The State Water Resources Control Board (State Board) has established a goal to increase statewide use of stormwater from 2007 use by at least 500,000 acre-feet per year (AFY) by 2020 and at least 1 million AFY by 2030 (State Board Resolution 2009-0011; Policy for Water Quality Control for Recycled Water), largely by capturing local runoff in and near developed areas. The California Urban Water Agencies (CUWA) consider urban stormwater one possible element of a sustainable, diverse portfolio of water supplies.

Urban runoff originates from developed areas with significant impervious surfaces and is typically generated in large volumes over short periods. To reduce flooding risks, urban stormwater is often quickly redirected from developed areas to receiving waters, and because it can contain high pollutant concentrations, treatment is sometimes needed to protect receiving waters.

For years, flood protection and water quality have been the primary focus of urban stormwater management. However, the need for new local water sources has shifted attention to the possibility of capturing more urban runoff for beneficial use as a supply. These stormwater capture projects can support a range of benefits, such as urban environment/amenities and recreation as well as water supply enhancement.

Stormwater capture and use can be accomplished via several methods:

- Upcountry runoff collection in reservoirs as a raw surface water supply
- Groundwater infiltration basins
- Urban runoff collection in reservoirs followed by treatment for non-potable uses
- Diversion into wetlands
- Percolation through semi-permeable pavement or land
- Diversion to bioswales, rain gardens, and other similar distributed systems
- Onsite collection in rain barrels or cisterns for non-potable uses

The appropriateness of a stormwater capture approach is site-specific and highly variable based on local rainfall and water demand patterns, geology, groundwater quality, and type of land development.

Stormwater Capture Is an Integral Part of Water Supply

Most of California's existing stormwater capture is accomplished through surface water reservoirs that collect upcountry runoff to supply potable water and irrigation needs, while also providing flood protection and recreation for local residents and visitors. Local surface water reservoirs also capture high-quality stormwater in some areas with limited groundwater basins.

CUWA member agencies and their retail members actively collect and use approximately 540,000 AFY of local urban stormwater runoff, and they are working to expand this capacity. In the city of Los Angeles alone, recharge volume could double from 64,000 AFY to more than 130,000 AFY by 2035 at a cost competitive with more expensive imported water (LADWP 2015). In Northern California, CUWA agencies currently capture and use more than 100,000 AFY of urban stormwater and are looking to expand that number significantly.

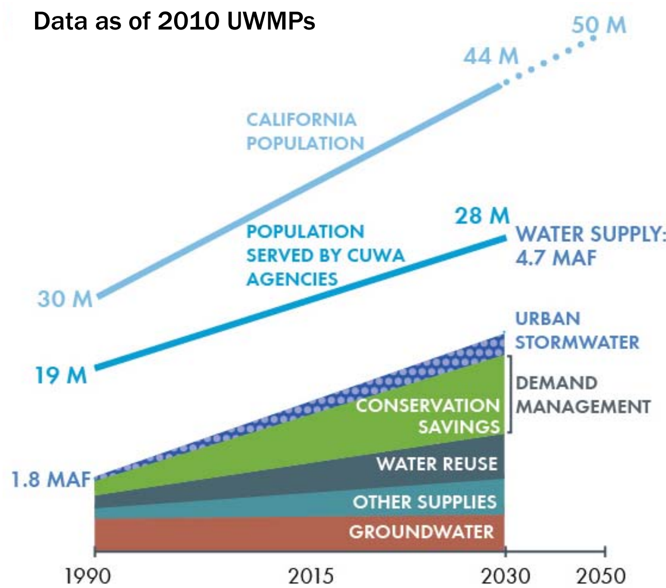

Figure 1-1. CUWA agencies aim to increase urban stormwater capture as one element of a diverse water supply portfolio.

Note: "Water supply" includes imported water (not shown).

Overall, urban stormwater is not a large portion of the CUWA water supply portfolio because of logistical and cost limitations (Figure 1-1). This is also generally true on a statewide basis. Most of the relatively easy-to-capture and better-quality water flow is already being collected. However, in areas with favorable conditions, stormwater could compose a significant amount of the total water supply. For example, the relatively large groundwater storage capacity in the Los Angeles area will enable more than doubling incidental and engineered infiltration of urban stormwater.

Expanding Urban Stormwater Capture in California

CUWA agencies and others are actively pursuing opportunities to capture urban runoff where site-specific conditions are conducive. The best opportunities often build on existing infrastructure, proximity to recharge areas, and partnerships with other agencies. Carefully tailoring urban stormwater projects to best suit local conditions will help provide the best range of benefits to the greatest number of entities and improve cost-effectiveness.

Urban stormwater capture—though not composing a large portion of the local water supply portfolio—continues to grow where cost-effective.

Maximizing storm flow yield in urban areas has inherent costs and logistical tradeoffs. For example, intermittent, infrequent large-flow events pose a challenge to capturing urban stormwater in California. In addition, environmental needs may restrict flow diversion. Major challenges and opportunities to expanding urban stormwater capture are further discussed below.

Urban runoff can be important to maintaining natural functions

Urban stormwater capture focuses on excess flows. However, the need to develop local water supplies must be balanced with minimum flow requirements for riparian habitat and the water rights of downstream users. In some places, stormwater capture projects are infeasible, inefficient, and/or expensive due to these competing needs for stormwater flows. In other places, stormwater capture projects can create opportunities for partnerships to address multiple issues.

The extent and types of projects should be tailored to local conditions

Opportunities for capturing more urban stormwater do exist, but the best solutions vary greatly by region. Climate is the primary challenge to using urban stormwater as a water supply. In California's Mediterranean climate, the rainy season does not coincide with the irrigation season, as it does in some other regions (Figure 1-2). Thus, runoff must be captured and stored for later use. Groundwater storage offers a much more cost-effective and practical approach than building large surface or aboveground storage facilities. While large-scale centralized urban stormwater capture typically depends on aquifer capacity, distributed projects also offer significant opportunities for multiple benefits.

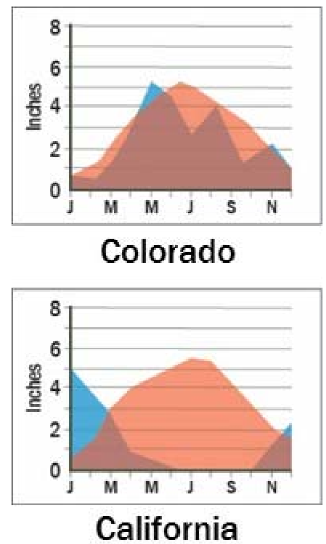

Figure 1-2. Unlike some other regions, California's Mediterranean climate provides rain (blue) in the winter and not in the summer, when irrigation needs (red) are greatest.

Source: WSTB-NAS 2015

Leveraging existing infrastructure and projects can create more opportunities for expanding urban stormwater capture

Since most of California's annual precipitation arrives in a few large rainfall events, capturing urban runoff for supply requires systems to move, treat, and store the water. Some required investments may include construction of costly and large infrastructure, such as basins, treatment facilities, conveyance pipelines, and pumping stations. Costs may be reduced by leveraging existing infrastructure (to the greatest extent possible) and using established flow patterns, nearby public spaces, and partnerships.

Sometimes other new alternative local water supplies are more cost-effective

In urban stormwater capture planning, the potential yield (amount of water recoverable) must be weighed against the costs of building and operating the new systems. Urban stormwater capture costs vary greatly based on site-specific conditions, such as infrastructure requirements to transfer, treat, and store the supply. The Los Angeles Department of Water and Power's (LADWP's) Stormwater Capture Master Plan shows that cost-effectives solutions exist across the various types of urban runoff capture systems if local conditions are favorable (LADWP 2015).

Several CUWA agencies have assessed the viability of capturing urban stormwater for supply. Their studies to date conclude that cost-effective opportunities for urban stormwater as a supply are limited in some areas, whereas other alternatives of new supply (reuse and desalination) may offer significantly more yield for the cost.

Partnering can help make new projects affordable

Urban runoff typically flows across multiple jurisdictions/service areas where separate entities manage stormwater, groundwater, and drinking water, which can result in overlapping regulatory and non-regulatory interests. Thus, capturing stormwater for supply requires a coordinated and complementary approach, often involving multiple stakeholders. Additionally, California has some unique and significant constraints to funding urban stormwater capture. Partnerships can offer cost-sharing opportunities to build urban stormwater capture systems that provide multiple benefits—such as local environment enhancement, water supply improvements, and/or potable water use offsets—while also supporting municipal separate storm sewer system (MS4) permit compliance. Existing projects can serve as examples of how costs and benefits can be allocated among potential project partners.

Fostering future expansion of stormwater capture targets the best candidate projects and makes the best use of limited funds

This white paper recommends several strategies and/or state initiatives to foster development of urban stormwater capture and reclamation projects. These strategies include:

- Providing guidance on how to develop and plan urban stormwater capture projects based on local conditions and cost per yield
- Advancing watershed management to improve water quality where urban stormwater is captured in local reservoirs
- Facilitating creation of local detention systems for multiple benefits
- Promoting development of capturing near-urban/suburban runoff (on the fringes or outside of highly urban areas) to maximize stormwater collection statewide

Such activities would support the state's overall goal by facilitating further development of stormwater as a supply, providing meaningful benefits at a reasonable cost, and expanding the range of potential opportunities.

Conclusions

Stormwater is an integral part of the state's water supply portfolio. For many years, runoff has been collected in upcountry and local surface water reservoirs. Building systems to capture urban stormwater for supply is particularly challenging in areas lacking groundwater capacity due to the logistics and costs of the extensive infrastructure required to move, store and treat the water. CUWA agencies' programs range from distributed consumer-involved programs on individual properties or neighborhood/district-scale programs to centralized agency-driven projects that involve recharging groundwater and using existing reservoirs. CUWA agencies continue to plan and develop new multi-benefit urban stormwater projects where feasible and cost-effective for improved beneficial uses, flood protection, environmental enhancement, and water supply.

SECTION 2

Introduction

Growing interest in urban stormwater as a potential water supply in California has led to suggestions that water suppliers take a more active role in developing and funding this resource. This white paper aims to inform the ongoing statewide dialogue by characterizing current use of stormwater as water supply and the opportunities and challenges associated with its expansion in urban areas.

The State Water Resources Control Board (State Board) established a goal in its Storm Water Strategy to increase statewide use of urban stormwater over 2007 use by at least 500,000 acre-feet per year (AFY) by 2020, and by at least 1 million AFY by 2030 (California Water Boards 2016).

Others besides state agencies share an interest in the use of urban stormwater, including water, wastewater, and flood management agencies; nonprofits such as the Public Policy Institute of California, California Water Foundation; and others. Pending legislation (e.g., Senate Bill [SB] 20, the California Water Resiliency Investment Act) is considering urban stormwater a chronically under-funded water need. Some have suggested leveraging urban stormwater management efforts, under increasingly stringent water quality permitting rules, to transform urban runoff into water supply.

The CUWA agencies consider urban stormwater an element of "One Water"—an integrated approach to managing finite water resources in a sustainable manner that recognizes the interconnectedness of surface water and groundwater supplies, stormwater, and wastewater.

WHO IS CUWA?

Established in 1990, California Urban Water Agencies (CUWA) is a nonprofit corporation of 11 major urban water agencies that collectively deliver drinking water to more than two-thirds of California's population. Together, CUWA member agencies invest nearly $3 billion each year in capital projects to deliver water reliably.

CUWA MEMBER AGENCIES

- Alameda County Water District
- Contra Costa Water District
- East Bay Municipal Utility District
- City of Fresno Water Division
- Los Angeles Department of Water and Power
- Metropolitan Water District of Southern California
- City of San Diego Public Utilities Department
- San Diego County Water Authority
- San Francisco Public Utilities Commission
- Santa Clara Valley Water District
- Zone 7 Water Agency

Stormwater Is an Integral Part of Water Supply

The State Board defines stormwater simply as "temporary surface water runoff and drainage generated by immediately preceding storms" (Water Code, Section 10561.5 [b]). For the purposes of this white paper, "upcountry runoff" is differentiated from "urban runoff." Upcountry runoff is defined as runoff from undeveloped and minimally developed areas; these areas are characterized by largely permeable land surfaces with minimal or no human activity.

Much stormwater is currently captured, largely in upstream watersheds.

Statewide and multi-state upcountry runoff originates mostly from undeveloped lands, with a comparatively small contribution from developed areas, and is collected in creeks and reservoirs that can serve as water sources throughout the state. California's major reservoirs rely on stormwater—including snowmelt, which is runoff from winter storms that is temporarily stored upcountry as snow. Concerns have been raised that much of California's stormwater flows into the ocean. However, many existing stormwater capture projects do collect a large volume of rainfall runoff, primarily in upcountry areas where collection is more economically feasible and water quality is significantly better than in urban areas.

While upcountry runoff is an important part of California's water supply portfolio, this white paper focuses on urban stormwater—runoff from developed areas with significant human activity and large amounts of impermeable and semipermeable pavement and buildings. Large volumes of urban runoff are typically generated over short periods. However, typical urban stormwater events should not be confused with flood flows. This white paper considers average stormwater flows that occur much more frequently than large flooding events.

Urban Stormwater Management Addresses Multiple Needs

Urban stormwater management addresses a range of issues. Historically, surface runoff has been redirected out of the local vicinity quickly (e.g., into collection systems) to reduce the possibility of local flooding, especially from significant storm events. In urban areas, stormwater can potentially contribute high concentrations of pollutants (e.g., nutrients, pesticides, road oils, grease, heavy metals, and trash) to receiving waters such as rivers, the ocean, and estuaries—and cause erosion problems if not properly managed.

In 1987, Congress amended the Clean Water Act to address water quality impacts from urban stormwater (Section 402[p](2)). Agencies are now required to obtain National Pollutant Discharge Elimination System (NPDES) permits for urban stormwater discharge. Since the U.S. Environmental Protection Agency's (EPA's) enhanced urban stormwater control regulations went into effect in 1987 (in response to Clean Water Act revisions), management of urban stormwater and dry weather runoff has generally focused on water quality and impacts of discharge on receiving water bodies. Runoff from urban areas, industrial facilities, and construction sites can be a significant source of pollutants, and has contributed to inland and coastal water quality impairments throughout California. Medium-to-large sized

Flood protection and water quality improvement have traditionally been the focus of urban stormwater management. The need for new local water sources has turned attention to the possibility of capturing more stormwater for reclamation.

municipalities[1] are regulated by municipal separate storm sewer system (MS4)[2] permits that are becoming increasingly stringent with every permit cycle. MS4 permits must have compliance plans to manage water quality and runoff. As a result, urban stormwater is now managed with the following goals:

- Controlling and preventing destructive flooding to the greatest extent practicable
- Equalizing flows in combined sewer systems to minimize water quality impacts on receiving waters and to attenuate peak flows
- Providing environmental flows to riparian habitats
- Developing and implementing best management practices (BMPs) to reduce the release of trash and pollutants into runoff from industrial and commercial sources during rainfall events to protect receiving groundwaters, surface waters, oceans, and estuaries
- Developing and implementing BMPs to treat, reduce, or delay stormwater runoff via rainwater harvesting to comply with regional or local MS4 permits

MS4 permittees are generally distinct from water suppliers, and stormwater management agencies are often funded and administered by cities and counties. No formal regulations are associated with groundwater recharge from urban stormwater, although recent Los Angeles County MS4 permit revisions provide a framework for cities to plan and build aquifer recharge systems that could serve as a starting point for others with a similar interest and hydrogeology. Urban stormwater capture projects can often provide multiple benefits, such as enhancing the local environment and/or offsetting potable water use while positively impacting MS4 permit compliance by reducing flood risk and helping to address stormwater impairments.

Stormwater Capture Can Be Done a Number of Different Ways

Stormwater is typically captured in one of the following ways:

- Collecting upcountry runoff in surface water reservoirs
- Recharging groundwater (Figure 2-1):
  - Collecting and recharging stormwater into groundwater aquifers via direct injection or infiltration basins
  - Diverting stormwater into wetlands
  - Percolating stormwater through semi-permeable pavement (“self-mitigating pervious pavement”)
  - Percolating stormwater through permeable surfaces such as undeveloped floodplains and agricultural land
- Collecting urban runoff in reservoirs, followed by treatment for non-potable uses (Figure 2-2)
- Diverting local runoff into bioswales, rain gardens, and other similar distributed capture methods
- Collecting and using urban runoff on site to supplement or to replace irrigation (Figure 2-3). With proper treatment and permitting, the runoff may also be used for toilet and urinal flushing

[1] Phase I permits are required for municipalities with populations of 100,000 or more. Phase II permits are required for municipalities with populations less than 100,000.

[2] MS4 systems are those where stormwater discharges are separate from municipal storm sewer systems.

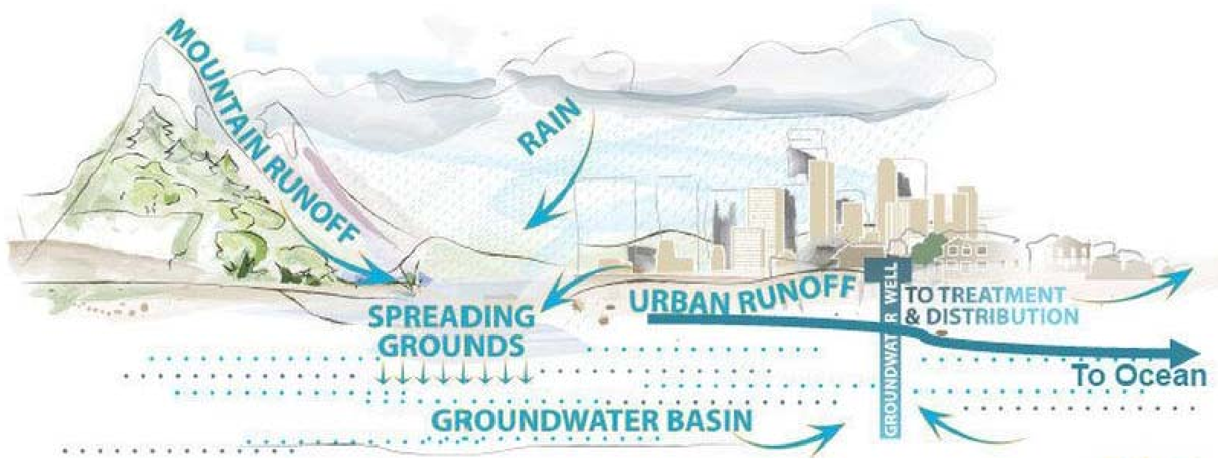

Figure 2-1. Stormwater can be captured and used to recharge groundwater if the geology is conducive.

Courtesy of LADWP

Figure 2-2. Centralizing urban stormwater capture systems usually requires large storage basins, like the City of Chicago's 25,000 AF basin. Locating a similarly sized basin in California would be challenging, and it would sit empty for the long dry season.

Photo courtesy of Metropolitan Water Reclamation District of Greater Chicago

Figure 2-3. Roof runoff can be captured in rain barrels or cisterns to offset a small to moderate amount of potable water use.
Photo courtesy of LADWP

Engineered systems that capture urban runoff typically provide some level of treatment prior to discharge into the groundwater via an infiltration basin or gallery. The captured water may be settled (to allow suspended matter to settle out) and filtered (to remove oil and grease particles). In areas that receive runoff from vehicle-heavy roads, urban stormwater catch basins may also include oil and grit separators prior to releasing flow into waterways (Begum, Rasul, and Brown 2008). Stormwater routed to an infiltration basin or gallery recharges groundwater and also benefits from soil aquifer treatment, a passive treatment that occurs as the captured runoff percolates through the vadose (unsaturated) zone into the underlying aquifer layers. However, soil aquifer treatment may be inadequate to treat stormwater from predominantly urban/industrial areas.

Depending upon the urban stormwater source and intended use, additional treatment may be required. In existing systems where the planned use is in cooling towers, irrigation, or for eventual potable supply, treatment could involve standard flocculation and precipitation, followed by filtration and then chemical or ultraviolet light disinfection. No consistent statewide guidelines exist on the appropriate water quality for urban stormwater as a supply; however, Los Angeles County has developed comprehensive guidelines that could serve as a model for others.

The wide range of potential benefits from capturing urban stormwater include urban environment/amenities, recreation, water supply enhancements, and water quality protections to receiving waters. For example, California's system of surface water reservoirs captures upcountry runoff and stores it as potable water supply. These reservoirs also provide flood protection and recreation for residents and millions of visitors each year. On a smaller scale, vegetated swales in building developments can enhance the local environment while also providing flood protection. In addition, they can also provide aquifer recharge in areas with accessible formations. The appropriateness of different types of stormwater-capture methods for a location depends upon the hydrologic (rainfall patterns), geologic, and land development characteristics of that area.

The State Board Supports Urban Stormwater Capture

The State Board and Regional Water Quality Control Boards are actively involved in initiatives to expand the management of urban stormwater as a resource to maintain and restore infiltration/recharge and achieve multiple benefits, including water supply augmentation and groundwater recharge. Within the *California Water Plan 2013 Update*, Urban Stormwater Runoff Management (Figure 2-4) is a resource management strategy identified and linked to other resource management strategies (Department of Water Resources [DWR] 2013). The State Board recently approved a Storm Water Strategy that presents plans and goals for enhancing urban stormwater capture (California Water Boards 2016).

Figure 2-4. DWR's urban stormwater management strategy is intended to enhance other strategies in the California Water Plan by promoting stormwater as a resource where capture and use can benefit watersheds.

Adapted from California Water Boards 2016

The goal of the State Board strategy is to "lead the evolution of storm water management in California by advancing the perspective that [stormwater] is a valuable resource, supporting policies for collaborative watershed-level storm water management and pollution prevention, removing obstacles to funding, developing resources, and integrating regulatory and non-regulatory interests" (California Water Boards 2016).

The practices and programs outlined in this white paper are intended to further inform and support the state's initiative and, where appropriate, to support other state rules like the Sustainable Groundwater Management Act (SGMA) and the State Board's Recycled Water Policy.

SECTION 3

Overview of Existing and Planned Future Urban Stormwater Capture Projects

Urban stormwater is captured through a range of projects—centralized and distributed—that vary based on local hydrogeology, climate, and geography. Urban stormwater does not have the potential to compose a large piece of the statewide water supply portfolio because of logistical and cost limitations, but it could be a more significant local water supply where conditions are conducive. Development of urban stormwater capture projects can also provide community enhancements and increase water conservation awareness.

Stormwater Is an Existing Component of CUWA Water Supply Portfolios

CUWA agencies are committed to leveraging urban stormwater as a water supply resource where feasible and cost-effective.

As stated in Section 2, CUWA member agencies in Southern California and their retail members currently capture and use approximately 540,000 AFY of urban and near-urban stormwater runoff and continue to expand their programs as appropriate. In the city of Los Angeles alone, current studies indicate that recharge volume could increase from 64,000 AFY to more than 130,000 AFY by 2035 at a cost comparable to more expensive imported water (LADWP 2015). In Northern California, CUWA agencies currently capture and use more than 100,000 AFY of urban stormwater and stormwater and are looking to expand that number significantly.[3]

Urban stormwater can compose a significant fraction of the local water supply under the right

[3] A large majority of the source for imported water supplies is from upcountry runoff captured in reservoir systems. However, this does not fall under the regulatory definition of "stormwater" (i.e., urban storm runoff managed under MS4 permits).

conditions. For example, the relatively large amount of groundwater storage capacity available in Los Angeles allows it to meet more of its annual water demand through incidental and engineered infiltration.

Stormwater capture programs generally range from distributed consumer-involved programs (i.e., parcel-based urban stormwater capture on individual properties, neighborhood/district-scale programs) to centralized agency-driven projects (i.e., city-, county-, or regional-scale programs). Existing centralized projects typically focus on groundwater recharge and collection of runoff from less developed areas into existing reservoirs. Distributed projects typically focus on direct use of captured stormwater, and often include a groundwater recharge component. These projects range from rain barrels in homeowners' backyards to large cisterns on larger (often commercial) properties that can capture tens of thousands of gallons for irrigation, offsetting potable water consumption and helping build consumer awareness and investment in water use efficiency. Some CUWA agencies also practice centralized urban stormwater capture where significant volumes can be cost-effectively captured. This method of capture usually involves leveraging existing local groundwater capacity for recharge water.

The scope and method of urban stormwater capture is significantly influenced by local climate, geology, and land use patterns (e.g., some areas in Southern California have large groundwater infiltration capacities compared to Northern California; so more groundwater recharge is practiced there than in the north). Some of the CUWA agencies' projects are highlighted in Table 3-1 below to illustrate the types of current practices being employed across the state. Although not detailed in Table 3-1, many CUWA agencies also provide rain barrel rebates and other similar programs to facilitate consumer participation in urban stormwater capture.

Table 3-1. Examples of Centralized and Distributed Urban Stormwater Capture Projects	
Centralized Projects	
Agency	**Project Description**
Alameda County Water District (ACWD)	ACWD has been recharging local groundwater with rainfall runoff for more than a century. ACWD captures and recharges an average of 19,000 AFY of upcountry stormwater and approximately 1,200 AFY of direct urban runoff, which percolates into the groundwater basin via the Quarry Lakes Groundwater Recharge System (Figure 3-1). Another 10,500 AFY of incidental recharge occurs annually from local rainfall.
Los Angeles Department of Water and Power (LADWP)	LADWP actively captures and recharges approximately 29,000 AFY of urban stormwater, along with another 35,000 AFY infiltrating into potable aquifers through incidental recharge.
Metropolitan Water District of Southern California (MWD)	From 1995 to 2004, an annual average of about 477,000 AFY of stormwater runoff was captured in spreading basins or other facilities for groundwater recharge within the MWD service area (MWD 2010). MWD also offers a regional rebate program for rain barrels and cisterns.

Table 3-1. Examples of Centralized and Distributed Urban Stormwater Capture Projects	
Agency	**Project Description**
City of Fresno	The Fresno Metropolitan Flood Control District's (FMFCD's) urban storm drainage system includes over 150 retention basins designed to capture stormwater from 1- to 2-square-mile drainage areas within the City of Fresno (Figure 3-2). FMFCD's stormwater conveyance and retention basin system protects the community from flooding during design storm events (2-, 5-, and 10-year events). The retention basins are connected to one another through a network of canals owned and operated by the Fresno Irrigation District (FID). The network of interconnected basins and canals allows stormwater to be transferred from basin to basin during the wet weather season to optimize basin capacity and groundwater recharge. During the non-wet weather seasons, the basins and canals are used to recharge surface water from Pine Flat Reservoir and Millerton Lake. Interagency cooperation between the City of Fresno, FID, and FMFCD recharges approximately 17,000 AFY of stormwater and 25,000 AFY of surface water.
Santa Clara Valley Water District (SCVWD)	Stormwater has been captured in SCVWD for more than 80 years, using local runoff for groundwater replenishment in managed recharge facilities. On average, SCVWD recharges more than 50,000 AFY of local runoff and sends another 6,000 AFY to drinking water treatment plants (Figure 3-3).
San Diego County Water Authority (SDCWA) member agencies, including the City of San Diego	The San Diego region benefits from an average of approximately 50,000 AFY of local runoff in surface water reservoirs, which have been in service for several decades. These reservoirs were constructed because local hydrogeology does not support significant groundwater recharge. SDCWA, the City of San Diego, and other partners also are collaborating on a Sustainable Landscapes Program that provides training and financial incentives to encourage homeowners to create landscapes that function as mini-watersheds, using less water and featuring stormwater capture elements (e.g., bioswales and rain barrels).
Distributed Projects	
East Bay Municipal Utility District (EBMUD)	EBMUD offers rainwater management classes to teach customers about installation of at-home rainwater capture systems using passive capture methods, the role of soils for stormwater retention, pollution prevention practices, landscape impacts, irrigation methods, and local codes and ordinances.
San Francisco Public Utilities Commission (SFPUC)	Currently, 24 constructed rainwater harvesting systems in San Francisco manage rainwater from 12.5 acres of newly developed rooftops. The systems represent nearly 450,000 gallons of storage. The primary driver for these rainwater harvesting systems is San Francisco's Stormwater Management Ordinance, which requires projects that create or replace more 5,000 square feet of impervious surface to manage stormwater runoff on site. The systems also have a synergistic relationship with the Non-Potable Water Ordinance (NPO) and other "green" codes. The NPO requires all new buildings with a total gross floor area of 250,000 square feet or more to be constructed, operated, and maintained using available alternate water sources (including rainwater) for toilet and urinal flushing, and for irrigation.

Figure 3-1. ACWD diverts rainfall runoff into former quarry pits for groundwater recharge. Once urban blight, these rehabilitated quarries are now the centerpiece of the Quarry Lakes Regional Recreation Area.

Photo courtesy of ACWD

Figure 3-2. Leaky Acres, built in 1970 by the City of Fresno, comprises 26 percolation ponds covering 225 acres, collecting stormwater for groundwater recharge.

Photo courtesy of City of Fresno

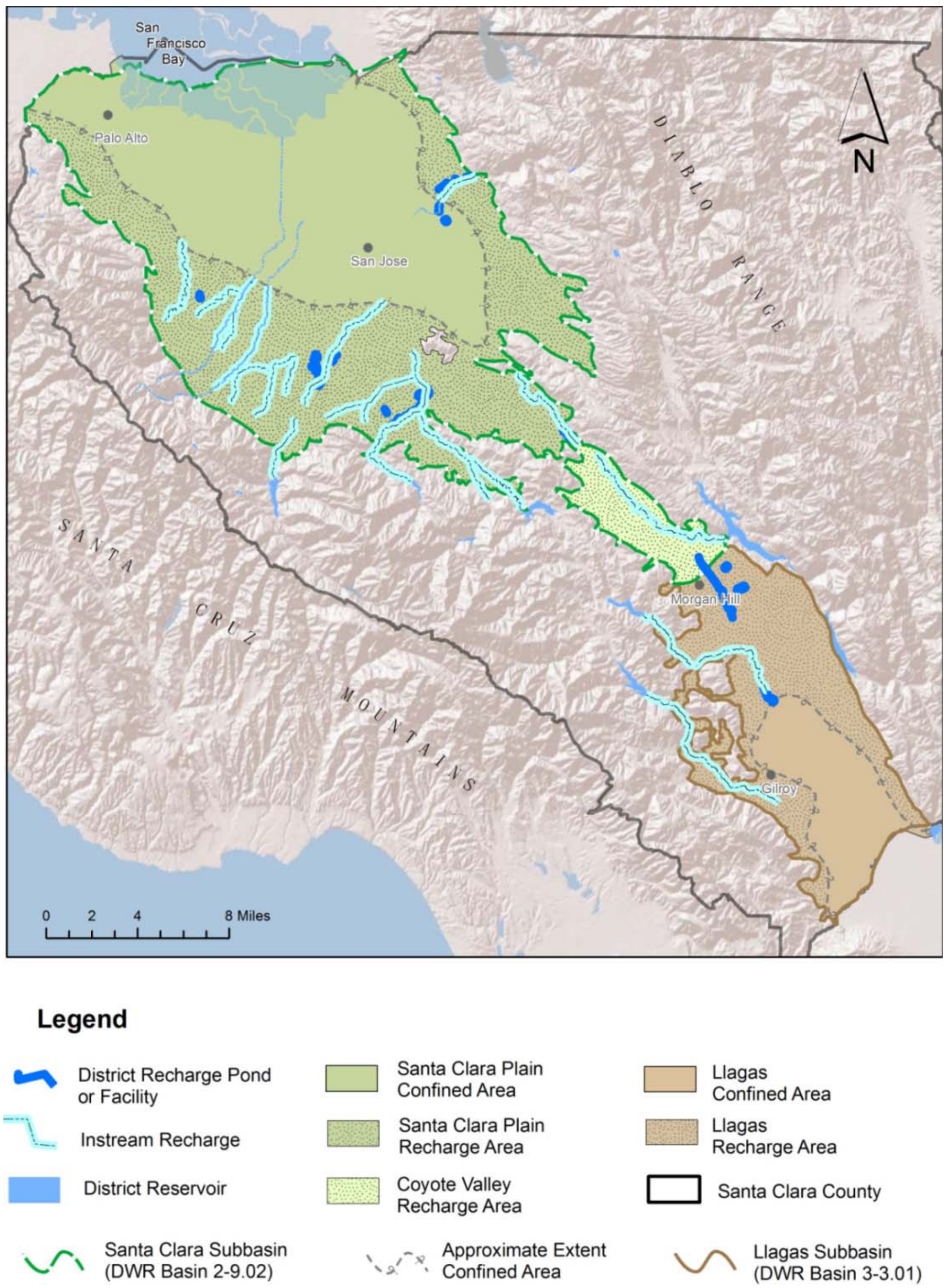

Figure 3-3. SCVWD captures 50,000 AFY of local runoff in managed groundwater recharge facilities and sends 6,000 AFY of local upcountry runoff to drinking water treatment plants.

Courtesy of SCVWD

Many of the larger, cost-effective stormwater capture projects have already been initiated. Exploration is ongoing of new urban stormwater capture projects to add incremental benefits. For example, EBMUD is evaluating opportunities for roof runoff capture and reuse. The best opportunities for capturing rainwater runoff for reuse is on larger sites such as schools and institutions (more potential to capture and reuse a significant portion of the rainfall) and in new developments, where the cost of installation is significantly lower than for retrofits (Environmental Science Associates [ESA] 2015). Roof runoff would not yield large volumes of water (composing less than 5 percent of the annual supply required by EBMUD); however, it builds water conservation awareness and offers customers the opportunity to reduce reliance on potable water supplies for landscaping irrigation. Larger, cistern-based projects allow for more substantial rainwater capture (and hence potable water use offset).

LADWP developed a Stormwater Capture Master Plan (LADWP 2015) that identified an additional 68,000 to 114,000 AFY that could be realistically captured in its large local groundwater basin through a suite of projects, programs, and policies over the next 20 years (Figure 3-4). Many of these projects are anticipated to leverage other, ongoing projects in the vicinity of the new capture systems and benefit from partnerships with stormwater management agencies and other stakeholders to share costs.

A number of potential urban stormwater capture projects and programs have been identified in the MWD service area outside LADWP. These projects range from large, centralized recharge basins to small-scale distributed urban stormwater direct-use projects. If implemented, an additional 45,000 to 56,000 AFY of urban stormwater could be captured (MWD 2010). More potential projects and programs are anticipated to be added to the initial list as regional urban stormwater programs move forward.

SCVWD is also developing other potential opportunities to increase urban stormwater capture through its One Water Plan and Water Supply Master Plan update, including centralized groundwater recharge and distributed projects.

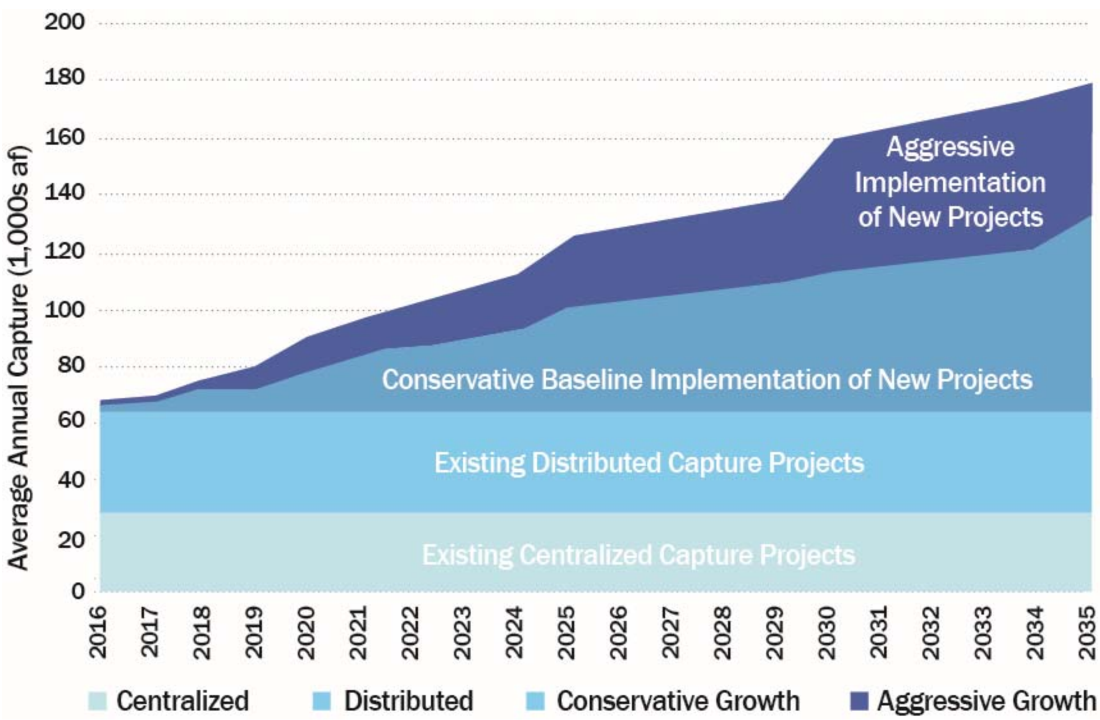

Figure 3-4. Further significant increases in urban runoff reclamation typically come at a higher cost. Potential new projects will require careful evaluation of the total cost per additional unit of water yield.

Source: LADWP 2015

SECTION 4

Challenges and Opportunities for Developing Urban Stormwater Supplies in California

Using urban stormwater as a supply presents challenges related to water rights, environmental requirements, costs, and implementation. However, forming partnerships, coordinating efforts with other projects, using existing infrastructure, and focusing on areas with available storage capacity can improve project feasibility and reduce cost impacts.

The Extent and Types of Urban Stormwater Capture Projects Should Be Tailored to Local Conditions

Opportunities for cost-effective large-scale urban stormwater capture for local water supply enhancement are more limited in California than in other parts of the country. In California's Mediterranean climate, the rainy season does not coincide with the irrigation season (Figure 4-1), and large-scale storage is needed to hold rainwater for later use. Other countries that have made significant use of urban stormwater capture, like Australia, do so in areas where rainfall and irrigation needs coincide (Figure 4-2).

Annual precipitation amounts also vary across California, with the northern parts of the state typically receiving significantly higher amounts than the south. Drought conditions can make urban stormwater a less reliable source of supply, depending on the water year, and the implications of climate change effects could make precipitation patterns more extreme. Water agencies throughout California must consider their unique local conditions to determine the size and types of urban stormwater capture feasible for their service areas.

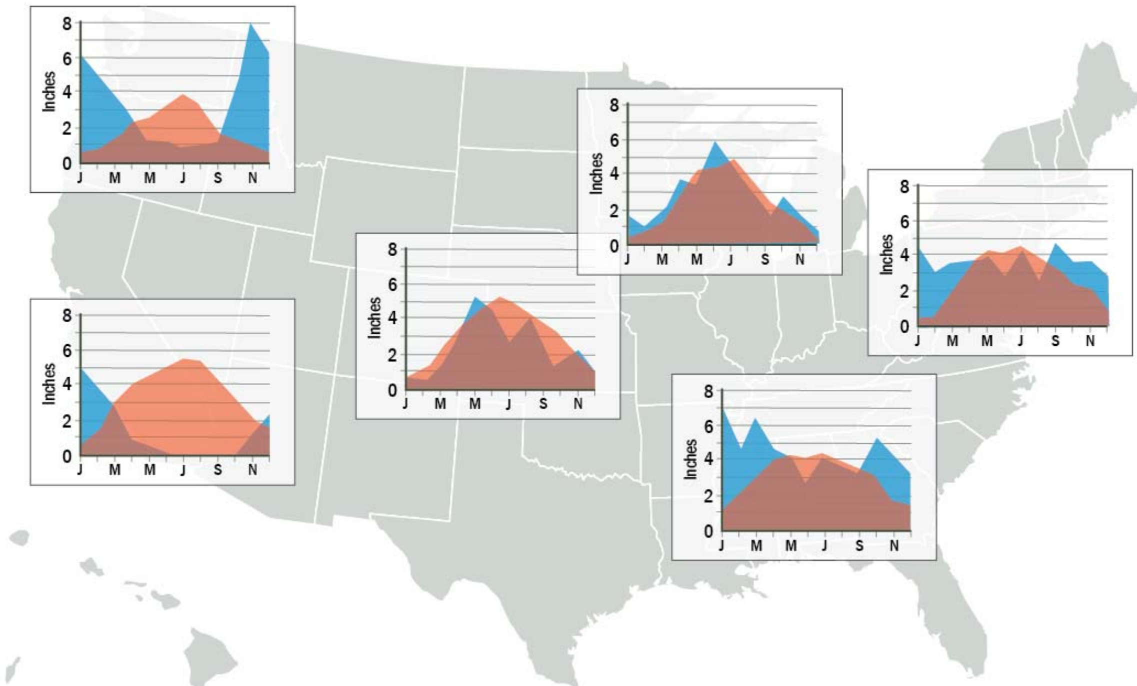

Figure 4-1. Leveraging available rainfall (blue) for irrigation (red) is more difficult in California than in other parts of the country, where demand peaks coincide with rainfall peaks.

Source: WSTB-NAS 2015

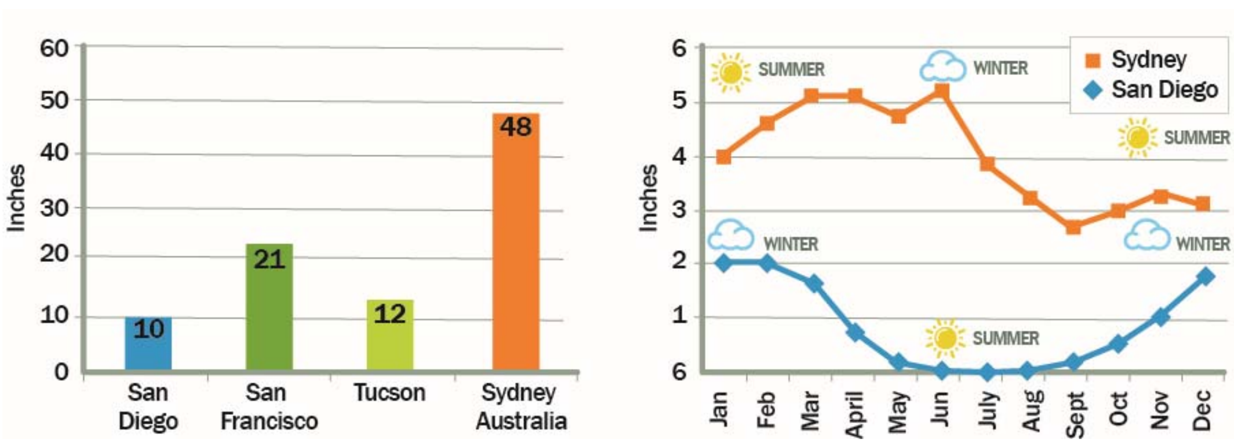

Figure 4-2. Rainfall totals during high water demand periods are significantly less in California than in other semi-arid cities with extensive stormwater programs, such as Sydney, Australia.

Graphics courtesy of: City of San Diego, left, and adapted from the National Weather Service and Australian Bureau of Meteorology, right

Groundwater Recharge Offers the Best Opportunity for Large-Scale Urban Stormwater Capture

Capturing urban runoff for groundwater recharge has been shown to be one of the most cost-effective approaches. Optimal applications vary regionally and depend greatly on availability of aquifer storage, ability to infiltrate stormwater, and existing groundwater quality.

Groundwater basins differ in composition and structure. Local geology (aquifer and soil properties) and source water quality dictate recharge rates and the need for pretreatment prior to infiltration. Source water protection is the first barrier of a multiple-barrier approach for ensuring the safety of drinking water. To protect groundwater quality, captured urban stormwater may need significant treatment before release into recharge basins.

All these factors must be considered in evaluating the potential capacity of a prospective recharge location. For example, Los Angeles County has an extensive stormwater basin system already being used for recharge, and has capacity for more, but nearby San Diego County has comparably limited recharge capacity in its local aquifers. Thus, implementing an extensive stormwater basin system in San Diego County would not yield the same results as in Los Angeles.

Efforts Should Focus on Targeting the Most Cost-Effective Urban Stormwater Capture Projects

A mismatch between winter storms and summer irrigation demands presents a major storage challenge.

Increasing the total volume of urban stormwater capture across the state presents significant challenges. It would require the addition of substantial centralized storage, as the bulk of California's annual precipitation typically arrives in a few large rainfall events. Distributed systems do not offer the same capacity for runoff capture and storage. For example, in an average rainfall year, a single-family residence in EBMUD's service area will generate about 27,000 gallons of roof runoff (ESA 2015), with most flow arriving in a few short periods in the winter—far more volume than could be captured and stored by an average homeowner. In many areas, significant infrastructure investments in centralized systems would be needed to capture urban runoff in large basins (on the order of hundreds of thousands of acre-feet), move it through pipelines and pump stations, and treat it before infiltrating or using as a potable water supply.

Leveraging existing infrastructure and projects can improve project economics

The cost of constructing a new centralized system can be prohibitive. However, the economics can significantly shift when using existing infrastructure to convey runoff to a location where it can be easily diverted and managed for beneficial use (e.g., infiltration). In addition, scheduling the work to coincide with other planned local projects can provide opportunities to offset capital costs and shift the business case from infeasible to cost-effective.

By coordinating internally and with other agencies, LADWP has been successful in building effective partnerships to advance their ongoing stormwater capture program. When a local stormwater management agency plans a project that will also yield water supply at a reasonable cost, LADWP will help implement the project, and the partner agency will assume facility ownership, operation, and maintenance responsibility. LADWP has also successfully diverted urban runoff from storm drains that pass next to parks or open spaces, reducing the need and cost for new infrastructure.

Site-specific factors strongly influence project yield and cost

In urban stormwater capture planning, the potential yield (amount of water recoverable) must be weighed against the costs of building and sizing new infrastructure. When designed for maximum (very infrequent) flows, infrastructure to transfer, store, and treat urban runoff can have very high capital costs relative to the total potential yield. Infrastructure requirements and yield are location-dependent, and yield is strongly influenced by the frequency of different rainfall patterns over time (i.e., the largest storms occur infrequently). LADWP's stormwater management plan shows that various types of stormwater capture systems can be cost-effective if site-specific conditions are right.

Life-cycle costs can range from less than $1,000/AF to more than $12,000/AF. Other new local water supplies are often less costly and can produce larger volumes.

MWD's and LADWP's recent evaluations of the lifetime costs per acre-foot of yield for various urban stormwater capture projects illustrates this point well[4]. The cost per acre-foot for urban stormwater capture varies widely as a function of project-specific details (Figures 4-3 and 4-4). Infrastructure requirements, proximity of use, and ease of storage all have a large influence on project cost relative to its capacity to capture water. In general, centralized infiltration projects tend to offer the highest yield per unit cost. The estimated cost of potential centralized urban stormwater projects in MWD's service area vary from approximately $500/AF to over $7,000/AF, depending on conditions. At the high end, that amount is more than twice the cost of other local supply development, such as seawater desalination and purified water reuse, which is itself often significantly more expensive than the use of existing water supplies. LADWP's estimated costs for centralized projects are lower, at less than $100/AF to approximately $4,000/AF, although LADWP currently projects these estimated unit costs are low compared to actual field data once the projects are built.

These values highlight how site-specific factors strongly influence costs and project yield. There are good opportunities for expanding urban stormwater capture, but it is not a panacea. Projects with multiple benefits can offer the opportunity to positively shift the economics of some urban stormwater projects through partnerships with other agencies that traditionally manage stormwater, limiting the financial burden on one single agency.

[4] This paper reflects data developed by CUWA agencies. Other databases elsewhere may also be available.

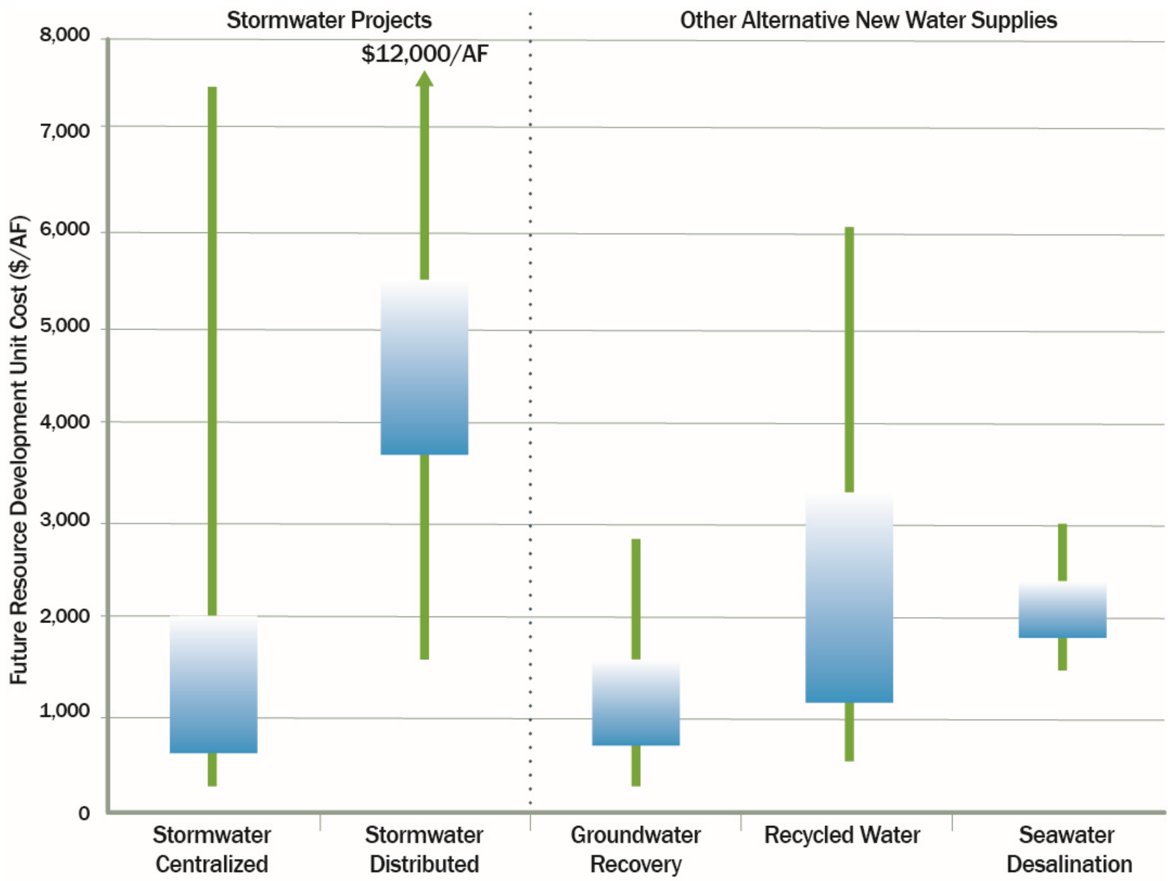

Figure 4-3. The unit cost of urban stormwater capture is often greater than for other alternative water supplies, though there are incremental opportunities for new projects. *Source: MWD 2015*

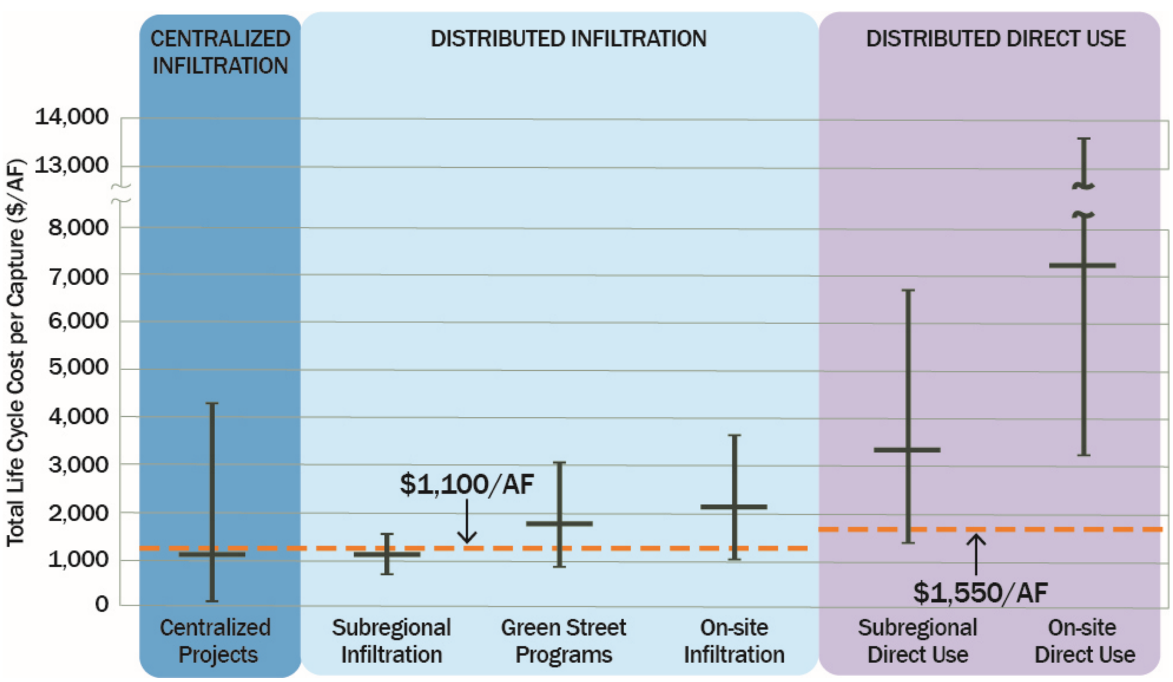

Figure 4-4. Groundwater infiltration often offers the most economical cost per yield; large urban stormwater projects are often infeasible where groundwater storage capacity is not available. *Source: LADWP 2015*

Partnering on Projects with Multiple Benefits Can Help Make New Projects Affordable

The responsibility for managing urban stormwater is not always clear given that it typically flows across multiple jurisdictions. Using urban stormwater as a water supply often requires coordination among various agencies and/or internal departments that manage stormwater, groundwater, and water treatment and distribution, as well as regulators.

Urban stormwater capture and use often requires new governance structures or agreements.

As discussed previously, many stormwater projects provide multiple benefits—support of MS4 permit compliance through increased flood protection, urban environmental enhancement, improved water quality, and a new local water source to recharge groundwater or offset potable water use. CUWA agencies continue to develop partnerships with stormwater management agencies to garner multiple benefits from these projects.

There are significant constraints to funding urban stormwater capture projects that are unique to California (e.g., Proposition 218 requirements). Cost-sharing through partnerships among multiple project beneficiaries can improve project affordability and support development of larger projects than would otherwise be possible. However, depending on institutional structure, some agencies may be tapping the same overall agency budget for various benefits.

In most cases, development of new large-scale urban stormwater capture and use projects will require new governance structures or agreements. Sharing project benefits and costs will help foster the establishment of such partnerships.

In general, implementation of stormwater recharge projects may be institutionally easier in adjudicated groundwater basins where management agreements and institutional bodies are in place. For these basins, the courts divide and allocate groundwater rights among multiple parties that withdraw water from the same aquifer, and establish watermasters and enforcement mechanisms for treatment. However, management of most groundwater in California has historically been unregulated. This is quickly changing with implementation of SGMA, which will require successful collaboration and evaluation of compliance approaches, urban stormwater capture strategies, and funding options for capital improvement projects.

SECTION 5

Looking to the Future

Urban stormwater capture may not compose a large fraction of California's total water portfolio, but opportunities to develop new urban sources are possible.

Following are suggested strategies and state actions to foster development of urban stormwater capture and reclamation projects. These suggested efforts would help to support the state's Stormwater Capture Strategy (California Water Boards 2016).

- **Provide information and guidance** on how to develop and plan various types of urban stormwater capture projects considering site-specific factors. Inform interested agencies and stakeholders about costs, benefits, and logistical limitations associated with implementing different types of urban stormwater capture projects as a function of local conditions.
- **Present data as a cost per yield** (average year and dry year) to communicate the true costs associated with capturing urban stormwater under varying scenarios.
- **Develop new funding mechanisms** to facilitate implementation of urban stormwater management, capture plans, and project maintenance.
- **Look for opportunities in urban areas to develop onsite detention systems** that can enhance percolation and provide flood protection at a moderate cost.
- **Look for opportunities to advance watershed management** to improve water quality where urban stormwater is captured in local reservoirs. In some cases, urban runoff severely affects water quality in local reservoirs, or runoff must be diverted around reservoirs to protect water quality. Water quality issues may increase the costs of treating stormwater to drinking water standards and/or limit use as a supply. Proactive watershed management and discharge requirements are needed to protect water quality and maximize use.
- **Promote the development of capturing near-urban/suburban runoff** (on the fringes or outside of highly urban areas) to maximize stormwater collection statewide. For example, support the exploration and development of new lower-cost/higher-benefit alternatives for urban stormwater capture in rural areas, like field flooding (O'Geen 2015). In places with a large agricultural base, like Modesto, work is underway to evaluate the viability of directing local urban runoff onto fields to recharge groundwater and irrigate crops like almond trees (Holland 2016). These smaller rural projects might offer significant opportunities to optimize urban stormwater capture to help mitigate the state's overall water shortage and groundwater overdraft problems.

Conclusions

A large portion of the available upcountry precipitation runoff is currently collected in California's many surface water reservoirs, and CUWA agencies and others have significant urban stormwater collection projects in locations conducive to runoff capture and storage. CUWA agencies continue to plan and develop new urban stormwater collection systems where feasible and economical. But urban stormwater runoff is significantly different from other types of alternative water supply, such as reuse. Although logistical, geological, climatic, and cost factors may preclude further development of stormwater projects on a large enough scale to make a sizable contribution to the state's total water supply, strategic opportunities still exist for increasing urban stormwater capture for potable supply or supply offset. CUWA agencies continue to plan and develop new multi-benefit urban stormwater projects where feasible and cost-effective for improved beneficial uses, flood protection, environmental enhancement, and water supply.

References

Begum, S., Rasul, M.G., Brown, R.J. 2008. Stormwater treatment and reuse techniques: A review. Second International Conference on Waste Management, Water Pollution, Air Pollution, Indoor Climate (WWAI 2008). Corfu, Greece, October 26–28.

Department of Water Resources. 2013. *California Water Plan, 2013 Update*.

Environmental Science Associates (ESA). 2015*. EBMUD rainwater potential capture study, Final memorandum*.

Holland, J. 2016. Berkeley lab joins groundwater recharge study. *The Modesto Bee*, Agriculture Section. May 23. Retrieved from http://www.modbee.com/news/business/agriculture/article79461247.html on May 24, 2016.

LADWP (Los Angeles Department of Water and Power). 2015. *LADWP (Los Angeles Department of Water and Power) Stormwater Capture Master Plan*. August.

MWD (Metropolitan Water District of Southern California). 2010. *Integrated Water Resources Plan 2010, Appendix A.12 Stormwater/Urban Runoff Technical Workgroup Issue Paper*.

MWD. 2015. *Integrated Water Resources Plan, 2015 Update*.

O'Geen, A.T., Saal, M.B.B., Dahlke, H., Doll, D., Elkins, R., Fulton, A., Fogg, G., Harter, T., Hopmans, J.W., Ingels, C., Niederholzer, F., Sandoval Solis, S., Verdegaal, P. and Walkinshaw, M. 2015. Soil suitability index identifies potential areas for groundwater banking on agricultural lands. http://californiaagriculture.ucanr.edu. April–June. pp. 75–84.

California Water Boards (State Water Resources Control Board and Regional Water Quality Control Boards). 2016. *STORMS - Strategy to Optimize Resource Management of Storm Water*. http://www.waterboards.ca.gov/water_issues/programs/stormwater/storms/ch_1.shtml. Retrieved May 11, 2016.

Water Science and Technology Board—The National Academies of Sciences, Engineering, Medicine (WSTB-NAS). 2015*. Report in Brief—Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs and Benefits*. December.

SECTION 7

Abbreviations

ACWD	Alameda County Water District
AF	acre-foot/feet
AFY	acre-foot/feet per year
BMP	best management practice
CUWA	California Urban Water Agencies
DWR	Department of Water Resources
EBMUD	East Bay Municipal Utility District
EPA	U.S. Environmental Protection Agency
ESA	Environmental Science Associates
FID	Fresno Irrigation District
FMFCD	Fresno Metropolitan Flood Control District
LADWP	Los Angeles Department of Water and Power
MAF	million acre-feet
MS4	municipal separate storm sewer system
MWD	Metropolitan Water District of Southern California
NPDES	National Pollutant Discharge Elimination System
NPO	Non-Potable Ordinance
SB	Senate Bill
SCVWD	Santa Clara Valley Water District
SDCWA	San Diego County Water Authority
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act
State Board	State Water Resources Control Board