Strategy to Optimize Resource Management of Stormwater

Projects 1a Promote Stormwater Capture and Use and 1b Identify and Eliminate Barriers to Stormwater Capture and Use

Product 1–Final Report: Enhancing Urban Runoff Capture and Use

April 10, 2018

"Barriers are barriers if you allow them to be; but we can break through them with drive and perseverance" – Neal Shapiro, City of Santa Monica

STORMS
STORM WATER STRATEGY
CALIFORNIA WATER BOARDS

DIVISION OF WATER QUALITY

STATE WATER RESOURCES CONTROL BOARD

Prepared by Office of Water Programs | California State University, Sacramento

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACP	Alternative Compliance Pathways
APA	American Planning Association
APWA	American Public Works Association
ARCSA	American Rainwater Catchment Systems Association
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BMP	Best Management Practice
CASQA	California Stormwater Quality Association
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CWH	Council for Watershed Health
CWP	Center for Watershed Protection
DDW	Division of Drinking Water
DFA	Division of Financial Assistance
DWQ	Department of Water Quality
DWR	Department of Water Resources
EIFD	Enhanced Infrastructure Financing Districts
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GSA	Groundwater Sustainability Agency
IRWMP	Integrated Regional Water Management Plan
ITRC	Interstate Technology Regulatory Council
JPA	Joint Powers Authority
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NACE	National Association of County Engineers
NACTO	National Association of City Transportation Officials
NAFSMA	National Association of Flood and Stormwater Management Agencies
NMSA	National Municipal Stormwater Alliance
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Treatment Works
RHAA	Rainwater Harvesting Association of Australia
RAA	Reasonable Assurance Analysis
Regional Water Board	Regional Water Quality Control Board
ROW	Right of Way
SCM	Stormwater Control Measures
SGMA	Sustainable Groundwater Management Act
State Water Board	State Water Resources Control Board
STORMS	Strategy to Optimize Resource Management of Stormwater
SWRP	Storm Water Resource Plan
TMDL	Total Maximum Daily Load
TRB	Transportation Research Board
ULI	Urban Land Institute
Water Boards	State Water Resources Control Board and Regional Water Quality Control Boards
WEF	Water Environment Federation
WERF	Water Environment Research Foundation

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Executive Summary

Water conveyance and storage infrastructure moves water from areas of availability to areas of demands. These can include municipal, agricultural, and specific environmental uses. Water conveyance is highly time-dependent, being built to deliver water not only where, but also when, it is needed. In California, state and federal agencies built large-scale infrastructure systems for moving water from Northern and Eastern areas to municipal and agricultural users along the Coast and Central Valley (Hanak et al. 2011; Hundley 2001). Population growth and increasing water demands are driving many municipalities to invest in alternative sources of water supply beyond conveyance and imports. In particular, local capture and use of urban stormwater runoff is becoming a more attractive source as out-of-basin supply becomes less reliable and access becomes more competitive (LADWP 2016; Santa Monica 2014) . Costs of out-of-basin water supply (energy, delivery, environmental mitigation, etc.) are also increasing (MWD 2015), providing further motivation for better management of local water resources.

Consequently, capture and use has been focused on supporting water supply through either capture and tank storage for direct use or recharge of useable aquifers (NAS 2016). Because the State Water Resources Control Board (State Water Board) aims to support valuing stormwater as a resource and encouraging active capture of urban runoff, a definition of urban runoff capture and use was developed: the intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems. This new, broader definition expands on the traditional view by recognizing ecosystems as a potential user of urban runoff. A primary objective of this report is to maximize the implementation of capture and use within a one water approach (U.S. Water Alliance 2016) by identifying projects to overcome barriers associated with justifying, funding, and administering capture and use projects.

The actions to overcome the barriers identified in this report will involve collaborative participation by public agencies, professional associations, and the general public. This report focuses on identifying key projects that will either provide incentives to implement capture and use projects or remove barriers that may prevent the implementation of such projects. Public agencies and professional organizations are identified in this report to either lead or advocate for certain projects. While public engagement will also be a critical component of implementing capture and use projects, this report develops concepts for future messaging efforts to emphasize the value of stormwater as a resource. The following sections summarize the findings, barriers, and potential advocates and partners identified within this report.

Summary of Barriers

There are a variety of barriers to stormwater capture and use and its implementation in California. The barriers listed in this report were identified by case studies as well as the experiences of the technical advisory committee (TAC). This section categorizes and summarizes these barriers. Additional information is included in Section 4 of this report.

Financing/Valuation

- Capture and use projects are often infeasible without augmentation from temporary funding sources.
- There is a lack of guidance to quantify all water and non-water benefits in a multiple benefit project to solicit additional funds.
- Transportation is a ubiquitous land use and the public right of way is the most common area to target for green infrastructure, however, integrating stormwater capture within transportation infrastructure can be challenging due to constraints on transportation funding.
- Stormwater infrastructure does not benefit from the same state and federal level of support provided to past water infrastructure investments (e.g., water supply and wastewater) and current state funding (e.g., Prop 1) is insufficient to cover proposed capture and use projects.

Education/Guidance

In this area, many tools, structures, and programs are lacking, including:

- Analysis tools for retrofit options on existing infrastructure including evaluation of potential water rights restrictions, particularly for flood control facilities.
- Outreach to increase understanding by the public and decision makers.
- Guidance on the design and applicability of new centralized capture and use systems.
- Guidance for designs specific to local conditions that account for soil types, instream flows, rainfall, climate, and demand.
- Guidance for storage limitations and treatment requirements for surface water long-term storage to avoid worsening water quality.
- Training on integrated water resource planning and the one water approach.
- Training on the appropriate scale and use of triple bottom line analyses to evaluate the social, economic, and environmental benefits of projects.
- Expansion of the Department of Water Resources (DWR) Water Management Planning Tool (through coordination between State Water Board staff and DWR) to incorporate stormwater infrastructure and analyze stormwater as a supply source.
- Guidance in the use of triple bottom line analysis to identify and evaluate the water source alternatives in the state's integrated watershed plans.

Institutional/Policy

- Varying municipal separate storm sewer system (MS4) permit post-construction requirements among Regional Water Quality Control Boards (Regional Water Boards) and the statewide NPDES permits makes creating statewide training programs and design guidelines for capture and use difficult.
- Stormwater conveyance systems may not be viable means to move stormwater to regional stormwater capture and use systems in cases where those conveyances have been determined to be "waters of the US" subject to receiving water limitations (RWL). If violations of RWL are probable, that would then require treatment to RWL standards prior to discharge to those conveyances, increasing treatment costs and possibly

requiring treatment systems or capture and use infrastructure in places that are not cost optimal.

- Lack of use points to a perceived regulatory barrier to implementation of drywell systems for capture and deep infiltration of stormwater in Northern California even though in Southern California there are many examples of drywells being implemented for this application.
- Inconsistent regulations for infiltration BMP siting and pretreatment requirements that are protective of groundwater resources in consideration of performance of different infiltrating practices such as drywells.
- Water districts, municipalities, and flood control agencies are not required to collaborate on water supply and capture and use projects and there are no mechanisms to share costs and cost-saving benefits. This can either make projects funded solely by stormwater funds cost prohibitive or preclude efficient placement of these facilities within the footprint typically under the control of stormwater agencies.
- There are no requirements to assess stormwater as a potential supply source in integrated regional water management plans (IRWMP) or municipal general plans. It is only recommended, but not required, to assess stormwater as a potential supply source in urban water management plans.
- Integration of water resources is not required; instead water resources (water supply, wastewater, recycled water, stormwater, and drainage) are integrated into developments independently.
- There are no requirements to analyze the environmental benefits and costs of urban runoff projects compared to other water sources, so capture and use systems are often undervalued.
- There is no requirement, and no uniform established methods, to assess the disruption to local watershed ecosystems and impact to groundwater due to excessive capture of stormwater and routing away from the area normally receiving the precipitation.
- There are no state-accepted treatment standards or technologies for direct, non-potable water use. (Ongoing work by the National Blue Ribbon Commission for Onsite Non-potable Water Systems will provide a basis for developing local and statewide standards.)

Technology

Technology was not reported as a limiting factor in the ability to implement capture and use projects in the case studies. However, innovative capture and use technologies can be better promoted for sites that constrain traditional approaches. For example, in high density development settings, innovative design for new buildings and roadways can promote integration of stormwater capture infrastructure with utilities and other infrastructure. Barriers to these approaches relate to policy, rather than technological capability.

Advocates and Partners

The public agencies and professional associations that may lead or advocate for certain projects to overcome the barriers listed in the previous section are identified where appropriate in the following sections. Additional information regarding the barriers, drivers, potential projects for statewide solutions, and lead agencies is included in Table 2. More information on additional resources identified in this report are found in Section 3.2.

Summary of Findings

These findings are meant to focus on how capture and use can be successful, despite the barriers identified in this report. These findings are also meant to inspire project proponents to implement capture and use and support projects that will eliminate barriers to maximize the likelihood of success for future capture and use projects. Additional information regarding the key findings of this study can be found in Section 5.

Motivating Change

Finding 1: Capture and use projects or BMPs that increase on-site runoff retention also reduce the effects and associated liability of discharging to local water bodies.

Finding 2: Public engagement is key to increasing BMP integration into other public and environmental objectives, which will increase the likelihood of robust, multiple-benefit, and cost-effective projects. Consistent and effective messaging is critical, according to the Project Advisory Group, and CASQA found that it requires specialized expertise and broad coordination (2017a).

Viable Urban Supply

Finding 3: Urban runoff can provide a sizeable source of water supply. In some parts of the state, stormwater runoff currently constitutes 10% or more of urban supplies.

Finding 4: Technological limitations were not reported in case studies. Instead, reported barriers relate to policy, finance, institutional structure, and awareness. Awareness of technological capabilities can overcome some perceived barriers. For example, space limitations and lack of permeability in near-surface soils are perceived barriers that can potentially be addressed by increased awareness of drywell technologies.

Finding 5: With California's highly variable climate and increasing urban demands, it is likely infeasible to meet all urban demands through stormwater capture alone. The scale of capture and use required to meet typical urban needs would necessitate volume storage that is many times greater than current stormwater management design storms. Additionally, because this volume of precipitation falls over a span of several storms throughout the year in most parts of the state, peak volume storage requirements would be extensive. Urban areas with underlying aquifers are better situated to capture and store water, as aquifers provide a cost-effective storage solution and a clearer path to overcoming existing storage barriers for capture and use. The city of the future should strive to use and reuse local water, including captured stormwater.

Better Information Needed

Finding 6: In most parts of the state, using urban runoff as a water supply is more expensive than utilizing existing sources. Distributed stormwater capture, which is easier to implement in dense urban areas, is more expensive, while larger centralized stormwater capture requires substantial tracts of land that can be hard to site in built-out areas. But, current water rates often do not accurately reflect full water supply costs. Existing water supply infrastructure was built and paid for in part decades ago, while environmental regulations and water scarcity are increasing current costs.

Improved rate-setting procedures in water districts could allow for better comparisons of existing and new infrastructure cost estimates. Water districts can contribute to proper valuation by using rate setting techniques that consider factors such as the environmental costs associated with different water sources and the cost increases associated with likely climate change scenarios. Water districts typically set standards based on a 5-year future projection, fundamentally limiting their ability to make investments in alternative water sources based on longer term changes (City of Vallejo 2016; LADWP 2016).

Finding 7: Standardized procedures or decision support tools do not exist for stormwater capture and use planning. Several major stormwater planning applications now include modules to support LID and BMP implementation, but cost and performance data is dispersed and few studies have effectively considered the potential for stormwater capture to comprise a significant source of urban water supply. Capture and use approaches are typically more expensive than upgrading existing grey infrastructure when comparing new vs. marginal cost increases, and when failing to include benefits and costs for environmental and social aspects of system management. Improving valuation of capture and use—both economic and non-economic—can increase community and political support, helping overcome financial and institutional barriers. Proper valuation of multiple-benefit projects will also make capture and use projects more attractive for various funding sources (e.g., transportation). Decision support tools can assist in optimizing new system designs with green and grey infrastructure that better promote sustainable and holistic water management, exemplified by one water approaches being pursued in some areas of the state.

Finding 8: Stormwater infrastructure can support multiple objectives, but these must be considered at the design stage. Centralized strategies better achieve multiple benefits when agencies charged with managing different types of natural resources collaborate to meet resource objectives (e.g., water supply, flood control, habitat, air quality, and receiving water protection). Decentralized strategies tend to be implemented within land uses that are primarily dedicated to other infrastructure (e.g., transportation) so choosing approaches that also support that infrastructure will be critical in marshalling funding designated for that infrastructure.

Finding 9: There are thousands of stormwater control measures (e.g., flood control facilities and stormwater detention basins) in California, so retrofitting or modifying existing regional facilities is a promising strategy to substantially increase capture and use. Resolving the uncertainty regarding existing water rights diversions and capture and use may encourage small scale retrofits where the cost of investigating rights is high compared to the benefit derived from the project. Central repositories for regional data on BMP, LID, and capture and use performance and costs would support better planning processes. In particular, databases for runoff and flood infrastructure— currently housed in more than 1,000 different flood control agencies statewide—could be brought together in regional databases in support of opening access to information that allows for better assessments of benefits (DWR 2013).

Tradeoffs and Consequences

Finding 10: Developing appropriate targets for capture and use requires considering the complex tradeoffs between benefits and potential unintended consequences, such as negative groundwater quality impacts. Also, existing ecosystems may have become dependent on current urban runoff flow regimes, so changing those flows will impact those ecosystems. A framework for valuing the support of different ecosystems would help further evaluate the effects of capture and use.

Hybrid Strategies

Finding 11: Future urban water management will require a mix of green and grey infrastructure. Costs, technologies, and social views are driving this trend toward hybrid systems. For stormwater, this means designing systems that use distributed infrastructure to capture and attenuate runoff throughout the landscape, coupled with key larger municipal infrastructure that assures performance. But best practices for design and management are unclear and risks are still significant. For instance, decentralized capture and use strategies on private land may not be well maintained over time. Alternatively, investing in large infrastructure is expensive and may not directly achieve receiving water requirements or estimates of groundwater recharge, stifling additional investments (Sedlak 2014; NAS 2016; Porse 2013).

Finding 12: Applying fit-for-purpose standards to the different uses of urban runoff may reduce unnecessary treatment costs. For example, risk-based treatment standards applied to harvested water for protection of public health based on likely exposure may result in decreased costs of direct use systems (SFPUC 2014).

Promising Actions

Potential projects are identified in Section 4.5. Projects that are recommended (immediately actionable) are included in Section 5.2 and touch on the following topics:

Local Actions

1. Collect data necessary for asset management and justification for stormwater fees. Develop costs for agreed-upon customer and environmental water resource service levels while minimizing life cycle costs (CASQA Actions 2.7 and 2.8).
2. Update municipal general plans to require consideration of stormwater as a water supply source (CASQA Action 1.1).
3. Align or leverage water services (e.g., water supply, flooding) with capture and use to the benefit of both (e.g., Hansen Spreading Grounds).
4. Use alternatives analysis tools to engage stakeholders and develop support for water infrastructure that delivers social, economic, and environmental benefits (CASQA Action 2.5).
5. Capture and use project advocates (e.g., water districts and MS4 programs) coordinate with local and state transportation authorities to look for opportunities for shared projects and benefits. (e.g., Elmer Avenue Stormwater Capture Project; CASQA Action 3.1).

State Actions

1. Explore options for funding stormwater capture and use (Projects 4A and 4B as well as CASQA Action 2.7).

2. Improve consideration of urban runoff in IRWMPs (CASQA Action 1.1).

3. Resolve the policy questions regarding use of promising technologies and approaches.
    a. Resolve regulatory and policy issues related to the use of drywells for stormwater management and clarify the minimum standards that local enforcement agencies would consider for local policy development (State Water Board).
    b. Update Integrated Regional Watershed Management (IRWM) guidelines and online tools to consider local urban runoff as a potential source (DWR).
    c. Improve land use codes governing building footprints to adopt performance standards for new development and redevelopment to support decentralized capture and use technologies, such as LID (municipalities).
    d. Establish a framework to assess local ecological impacts, positive and negative, to capture and use diversions (DFW, State Water Board).

4. Expand/improve regulatory performance measurements to reflect capture and use objectives (State Water Board).
    a. Develop/align post-construction stormwater control requirements for capture and use objectives based on factors such as watershed processes, public use needs, and ecologic value of current flow regimes.

5. Identify the most effective and feasible capture and use strategies.
    a. Evaluate the regional and statewide opportunity to retrofit conventional detention basins to enhance capture and use. The number, location, and volume of stormwater/flood control basins are a prime opportunity for significant benefit (DWR or provide funding to local flood and stormwater agencies).
    b. Establish design guidelines for public projects reflective of capture and use goals.

1 Introduction

Through this first-phase project, the State Water Resources Control Board (State Water Board) is laying a foundation of understanding on which to create and enhance incentives for implementing urban stormwater[1] runoff capture and use including:

- Developing a consensus definition of stormwater capture and use (Section 3)
- Evaluating technical approaches for stormwater capture (Section 3 & Appendix A)
- Identifying opportunities and barriers to stormwater capture and use, including legal, regulatory, technical, behavioral, fiscal, and policy areas, as well as actions that can be taken by the State Water Board and Regional Water Resources Control Boards (Regional Water Boards) to facilitate implementation of capture and use (Section 4)
- Identifying hydraulic and watershed-based methods to develop capture and use targets that can be used for site-specific sizing of capture infrastructure (See "Barriers Analysis" in Section 4)
- Identifying case studies that illustrate successful implementation of capture and use (Appendices B and C)

A primary purpose of this report is to maximize the implementation of capture and use within a "one water" approach by identifying projects to overcome barriers associated with proposing, funding, and administering capture and use projects. Embracing a "one water" approach focuses on promoting multiple benefits associated with capture and use such as protecting water quality and attenuating flood flows.

California has spatial and temporal distribution of precipitation that often do not align with water demand. Currently, water conveyance infrastructure, including canals, aqueducts, and rivers and streams, moves water from areas of greater availability to areas of greater scarcity, helping meet water demands for agriculture, industry, and municipalities (Hanak et al. 2011; Hundley 2001) throughout the state. Also, peak water demand for municipal and agricultural uses occurs during summer months when there is little precipitation. Water infrastructure moves captured runoff and snowmelt to meet those seasonal demands (DWR 2013). As demand grows and water imports from out-of-basin sources become less reliable, local urban stormwater capture and use will become more attractive as a source of water. Monetary costs of imported water supply—including the acquisition and movement of water along with associated energy requirements—are increasing (MWD 2015), further motivating better management of local water resources. Reducing imports can have additional benefits of retaining or restoring aquatic habitat and reducing greenhouse gas emissions with lower energy requirements.

California has three main resources for water storage: surface water impoundments, snowpack, and aquifers. When year-to-year surface water availability from impounds and snowpack decreases, use of aquifers increases. Groundwater is less susceptible to short-term drought,

[1] In this report, the term urban stormwater runoff is inclusive of rainwater, as defined in the Rainwater Capture Act of 2012 as "precipitation on any public or private parcel that has not entered an offsite storm drain system or channel, a flood control channel, or any other stream channel and not previously been put to beneficial use" (Wat. Code, § 10573). Some jurisdictions differentiate stormwater and rainwater (SFPUC 2014).

but some aquifers are in critical overdraft in much of the state (CNRA 2016) and during drought periods the consumption of groundwater is much higher (Xiao 2017).

Throughout Western North America, water sources are becoming further stressed. For instance, the Colorado River, which supports agricultural and municipal uses across seven states and Mexico, is over-allocated (Meyer 1966). A similar story is occurring for many water resources throughout the arid west, stemming from increased requirements for in-stream environmental water needs, highly cyclical climates with droughts that are expected to increase in intensity, and reduced snowpack. As municipalities look to plan for future water needs and growth, urban stormwater runoff may provide one option to address water resource challenges faced in California.

Why Urban?

In the West, the infrastructure for rural runoff capture for transport to regions of need is well-developed, often due to massive investment at federal, state, and local levels. In contrast, local use of urban runoff has not reached its full potential. To address this potential, this project focuses on urban runoff capture.

Why Runoff?

Not all water that flows from the urban environment is stormwater. In many cases, anthropogenic dry weather flows can provide a substantial amount of water. To consider as many potentially valuable sources of water as possible, all urban runoff is included in this project, not just stormwater runoff.

Stormwater can be captured and stored using a variety of methods. Stormwater capture can be accomplished by implementing best management practices (BMPs) that include green roofs, infiltration basins, detention basins, and bioretention raingardens. Captured stormwater can be stored for use on site using underground tanks and reservoirs or used to recharge groundwater. Use of stormwater to recharge groundwater is particularly attractive because aquifers are not as volume-limited as surface reservoirs (Lund et al. 2016). Further, groundwater extraction is not constrained by flood storage obligations and other rules that affect surface water reservoir operations, though groundwater extraction can be constrained by pumping rates, depletion cones, and temperature[2] management objectives for in-stream flows (Langridge et al. 2016). Another clear advantage of groundwater storage is that water can usually be claimed immediately without time limitation due to the higher storage capacity of aquifers and lack of constraints associated with flood storage obligations.

Stormwater capture can also support aquatic habitat preservation and restoration by reducing peak flows and volumes generated from impervious surfaces, yielding urban hydrographs that more closely resemble less-disturbed watersheds (Hollis 1975). To protect water quality, treatment may also be a component of hybrid systems that treat and release stormwater to surface waters.

[2] Overpumping groundwater dewaters streams which reduces flows resulting in increased stream temperatures (North Coast Regional Water Board 2015).

1.1 Goals

This project supports the overall mission of the State Water Board's Stormwater Strategy: to value stormwater as a resource. The goal of this project is to increase incentives for capture and use by identifying and proposing solutions to common barriers. The project concept is presented in the Strategy to Optimize Resource Management of Storm Water (STORMS) as Projects 1a and 1b. Follow up work is anticipated, as described in STORMS (State Water Board 2016). This project will help identify and refine some of that follow up work.

1.2 Objectives: Identifying Barriers, Constraints, and Incentives

A key step in identifying promising actions is analyzing impediments to capture and use projects. This must differentiate between constraints, the intrinsic realities limiting benefits and driving costs, and barriers that introduce inefficiencies in project delivery. Barriers, which result from a lack of knowledge or tools, institutional impediments (rules and jurisdictions), and public priorities, are the focus of this assessment.

Constraints strictly govern the design of a project and cannot be removed. Rainfall quantity and timing is a fundamental constraint of capture and use that cannot be manipulated (cloud-seeding aside). Other constraints that can influence project feasibility and drive costs or limit benefits include topography, geology, groundwater quality, existing water demand, proximity to water demand, timing of water demand, water rights, and the low cost of competing water sources.

Barriers, however, are problems that can be solved. In contemporary practice, solutions are often case-by-case or short-term. The resulting inefficiencies can drive up costs or dampen enthusiasm for progressive stormwater planning, yielding capture and use projects that fail to move beyond the initial planning stages. This project seeks to identify long-term solutions to these barriers for regions throughout California. Most barriers are based on unknowns and can be related to a constraint. For example, not knowing underlying geology is a technical barrier to developing a design. The solution is a site investigation. The result is quantification of the constraint—that is, the limitations of the geology to infiltrate and store water. Unknowns can be technical, financial, institutional, and even political or social. Barriers are the focus of this report. This report will also suggest the entities best poised to take action to address these barriers.

The underlying reasons for barriers are broad and complex. They reflect our past perspective of stormwater as waste rather than a resource. Perceived barriers often pose the most difficult barriers to mitigate or remove. While education may be sufficient to overcome some barriers of perception, local regulation, statewide policy, and even legislation may be necessary to overcome other perceived barriers to increase the level of comfort in implementing capture and use. Other barriers require improvements to our institutional structure, financial strategies, technologies, scientific knowledge, and regulations.

In addition to identifying barriers, this project also identifies incentives. Absent consistently available financial incentives, the primary strategy to increase incentives within this project is to identify ways to make planning, funding, permitting, and designing capture and use easier to implement and justify. The State Water Board has a separate STORMS project addressing funding.

1.3 Collaborative Approach

The State Water Resources Control Board and Regional Water Quality Control Boards (Water Boards) convened a Project Advisory Group (PAG) to provide input on the definition of capture and use and to inform the project team of the state of capture and use practices. The PAG was a volunteer group composed of the following entities:

- Department of Water Resources
- Los Angeles Department of Water and Power
- Los Angeles County Public Works
- Santa Clara Valley Urban Runoff Pollution Prevention Program
- AMEC Foster Wheeler
- Council for Watershed Health
- Environmental Protection Agency, Region 9
- California Stormwater Quality Association (CASQA)
- Torrent Resources
- UC Santa Cruz

Input and direction was also provided by the STORMS Core Implementation Committee, which is composed of the following entities:

- California Association of Sanitary Agencies
- California CoastKeeper Alliance
- California Council for Environmental and Economic Balance
- CASQA
- Association of California Water Agencies

The PAG met on October 17, 2016, to review the proposed capture and use definition, provide input on barriers, and to provide case studies that help identify possible solutions to capture and use barriers. That meeting resulted in the drafting of this report. The PAG met again on September 19, 2017, to review and comment on the key findings, barriers, and potential projects.

The Project Team, with Chris Beegan of the State Water Board as the project manager, included the following personnel:

- Brian Currier, Office of Water Programs at California State University, Sacramento
- Daniel Apt*, Olaunu Consulting
- Dominic Roques, Central Coast Regional Water Quality Control Board
- Dr. David Feldman*, University of California, Irvine
- Dr. Darla Ingles*, Low Impact Development Initiative
- Dr. Eric Stein*, Southern California Coastal Water Research Project

*Technical Advisory Committee (TAC) members

1.4 Report Organization

Section 2 of this report provides background on the evolution of stormwater infrastructure and management strategies. Section 3 presents the definition of capture and use as well as the goals of this phase of the ongoing effort by the State Water Board to encourage capture and use. Section 4 contains a discussion of current barriers, drivers, and factors affecting success. Section 5 summarizes key findings and corresponding constraints and barriers. It also suggests the most promising actions to increase capture and use based on impact and likelihood of success.

2 Background: Evolution of Infrastructure and the New Paradigm

To provide background for the identification and exploration of barriers, this section provides a review of stormwater management history and current practices, including a review of the types of public entities that have roles in water management.

2.1 California Stormwater Infrastructure and Changing Management Strategies

Most urban stormwater infrastructure in California is separated from sanitary sewer systems. Separated sewers are advantageous because they do not contribute to combined sewer overflows, where sewage can be released directly to watersheds during large storm events. However, many separate municipal stormwater systems were built with little or no water quality treatment until the advent of municipal separate storm sewer system (MS4) permits.

MS4s also have a legacy of moving stormwater to receiving waters as fast as possible. Before the onset of stormwater permitting, urban stormwater runoff was largely managed through flood control conveyance. First-order flood conveyance infrastructure—curbs, gutters, and drain inlets—was designed to drain flows quickly, preventing the collection of flood waters on urban roads and landscapes. Higher-order (downstream) conveyance infrastructure typically used storage in tanks and basins to attenuate flows, reducing the likelihood of exceeding the capacity of downstream conveyance. Channelized streams and rivers that moved the runoff were often constrained with walls or levees to protect adjacent properties. Generally, flood control systems were not designed for reduction of pollutants (NRC 2008).

The legacy of moving stormwater as quickly as possible also led to negative effects associated with hydromodification. Hydromodification occurs when urban runoff induces physical changes to local watersheds, landscapes, and surface drainage. Urban development is often associated with hydromodification (Stein et al. 2012). Modifications to land surfaces and runoff channels causes increases in surface runoff volume and rates. In particular, increased impervious surface cover, removal of topsoil and vegetation, and compaction of soils increases the amount of flow from a given amount of rain because the original shallow infiltration and retention of rainfall in soils is reduced (Miller et al. 2014). Impervious surfaces also increase the velocity of runoff by decreasing surface roughness, which increases the mobilization of pollutants (Pitt 1987). Dry weather stream flows can increase due to perennial discharge of wastewater effluent and nutrient runoff and/or groundwater seepage from leaks in subterranean drinking water supply and sewage collection pipelines (Townsend-Small 2013).

Adding impervious surfaces has four negative effects. First, increased flow velocities increase mobilization of pollutants on the land surface. Second, increased volume increases the erosive, channel-forming flows on downstream habitats (NRC 2008). Third, imperviousness decreases shallow infiltration and interflow to streams. Finally, impervious surfaces convey the many pollutants that comprise daily urban life.

Flood flow attenuation through retention can provide partial mitigation of hydromodification effects, but generally urban development produces a net increase in the magnitude and duration of critical, channel-forming flows on natural downstream systems that cannot be mitigated by traditional flood control infrastructure. Certain water quality BMPs, with some sizing modifications, have the ability to completely mitigate hydromodification (Stein et al. 2012). Current permits (e.g., NPDES Phase II) contain such requirements, but complying with typical hydromodification requirements can still result in a disruption in the water balance from the historic condition by allowing management practices to release water below channel-forming flows. The period of discharge can be greatly extended, so even after mitigating hydromodification effects, downstream wetland and aquatic habitats can still be affected.

Stormwater was commonly viewed and treated as a nuisance or danger. Managing it meant fast removal. A host of research through the 1980s and 1990s, however, began identifying the detrimental effects of stormwater runoff on local watersheds and aquatic habitat. In response, the National Pollutant Discharge Elimination System (NPDES) Phase I stormwater rulemaking evolved, and MS4 permits soon required pollutant reduction via stormwater treatment best management practices (BMPs) for new and redeveloping areas (USEPA 1991). The ultimate goal of BMPs was preventing exceedance of water quality standards that resulted, at least in part, from urban runoff. So urban runoff, which was previously viewed as physically destructive during large flows, was now additionally viewed as harmful during periods of low flows. The challenge for stormwater management became improving the quality of water and continuing to achieve flood protection goals.

While the majority of stormwater systems in California were designed simply to remove runoff, there are several notable exceptions that incorporate aspects of capture and use. For instance, the Fresno Metropolitan Flood Control District (FMFCD) made a concerted effort to build a flood control system in the 1960s focused on groundwater recharge and recreational benefits for both upstream flows and urban runoff (FMFCD 2016). In Los Angeles County, regional agencies have captured runoff to recharge local groundwater basins for decades. The Los Angeles Department of Public Works today operates a large system of interlinked upstream dams, channels, and spreading grounds across several watersheds, which can be used to divert flows from upper watersheds into a network of 25 spreading grounds in support of groundwater recharge (County of Los Angeles Department of Public Works 2006). The Irvine Ranch Water District (IRWD) also benefits from capture and use by diverting low-flow natural and urban runoff, as well as smaller storm flows, into its natural treatment system (NTS) of constructed wetlands throughout the San Diego Creek Watershed. In these wetlands, contaminants are removed and prevented from reaching Upper Newport Bay (IRWD 2012). And, the Orange County Water District (OCWD) has conducted stormwater capture for decades. Flows from the Santa Ana River, for example, are captured behind Prado Dam, the primary flood control facility along the river, via the Prado Wetlands, a specially-constructed wetland area that naturally removes nitrates and other contaminants for subsequent percolation into the groundwater basin (OCWD).

As a result of stormwater permits, new developments began to employ multiple-use basins for treating runoff and achieving flood flow attenuation. Post-construction requirements included low impact development (LID), but capture and use is often not prioritized or even recognized as an objective. This likely stems from the origins of LID as a method for older and often East Coast cities with combined sewers to meet stormwater permit requirements in the context of wet weather hydrology. As such, considerations like groundwater recharge were not the elements of primary concern. Capture and use has emerged in California as a result of the need for water supply, especially in downstream cities. Requirements for meeting Total Maximum Daily Loads (TMDL) as well as emerging alternative compliance pathways for meeting receiving water limitations (State Water Board 2015c) may steer permittees to meet MS4 requirements through on-site retention, which prevents discharges that would otherwise have to comply with receiving water limitations. Notably some localities such as the City of Los Angeles already require on-site retention up to a design storm. With most of these examples of capture and use, reducing the volume of urban runoff discharged to receiving waters is the primary mechanism by which water quality benefits are achieved. Because this reduction in volume is intrinsic to any capture and use strategy, capture and use is inherently beneficial to water quality in surface waters.

2.2 Valuing Stormwater as a Resource

The stormwater control measures, which are now primarily used for flood control, treatment, and hydromodification, have potential to achieve widespread capture and use of runoff. Doing so requires valuing stormwater as a resource. This movement is building. For instance, in 2008, the National Research Council outlined strategies for considering stormwater as a resource for water supply and recreational functions (NRC 2008). The California Water Boards have also recognized the importance of treating stormwater as a valuable resource where capture and use can result in multiple benefits within a watershed (California Water Boards 2016). This shift in perspective is also promoted in the California Stormwater Quality Association (CASQA) Strategic Plan (2010) and the CASQA vision statement (2017). These documents outline strategies to "Manage stormwater as a vital component of California's water resources in a sustainable manner, to support human and ecological needs, to protect water quality, and to restore our waterways." The original intent of LID involves valuing both stormwater and natural systems as resources that can work together to protect stream ecosystems by mimicking the pre-urban hydrologic model, with an emphasis on replicating the volume balance of runoff, infiltration, and evapotranspiration in urban catchments (Walsh et al. 2016).

Designing stormwater infrastructure to directly support ecosystems broadens the traditional approach to stormwater management. In this broader sense, retained stormwater can be put into soil where soil biota, macrophytes, and stream interflow systems improve water quality and ecosystems supported by baseflow or high groundwater. Ecosystem benefits include habitat improvement, increased food sources, carbon sequestration, pollutant uptake, reduced ozone (Nowak 2006), and reduced heat-island effects from plant growth. Improved baseflow results in decreased water temperatures and prolonged dry weather flows, and increased amounts and types of soil biota will aid in carbon sequestration and pollutant uptake (Klaus 2015).

Local stormwater capture can also lead to energy-saving schemes that (1) capture water before it becomes contaminated with the pollutants on streets and in sewers; (2) rely on energy efficient processes for removing contaminants; (3) treat water only to the extent necessary for intended use (fit-for-purpose water); and (4) obviate the need for diversion and large, centralized, energy-intensive treatment and distribution approaches. Stormwater capture and use can provide numerous co-benefits such as water quality improvement, green space, recreation and aesthetic value, wildlife habitat and corridors, carbon sequestration, pollination services, urban heat island cooling, increased property values, and improved public health and safety, as well as a much-needed supply of non-potable (fit-for-purpose) water in drought-prone areas (Brown 2009). See Appendix A for additional discussion regarding centralized and decentralized stormwater control measures (SCMs) and potential uses and ancillary benefits.

Stormwater capture can also reduce reliance on imported water from distant sources, which reduces inter-basin (or inter-region) transfers and polluted runoff. Stormwater supports the fit-for-purpose water supply concept by satisfying less sensitive water demands, such as certain household, landscaping, and commercial needs, with mildly polluted water. In a complimentary fashion, various grades of wastewater, which must be treated to a higher standard for reuse, can supply more sensitive uses. Finally, runoff from roads and driveways can be captured and harvested locally using distributed hybrid systems (for example, bioretention with an underdrain that feeds a cistern used for irrigation) configured to provide non-potable water for human use. The compilation of stormwater uses may also vary substantially among regions depending on climate, topography, geology, ecology, and human demands, and understanding these differences is critical to protecting surface waters (Walsh et al. 2016).

The National Academy of Science (2016) recognizes that urban runoff can be a part of the water supply portfolio even in areas like the arid southwest where meeting outdoor water demand was identified as a mismatch with rainfall seasonality. This report also evaluates using graywater to enhance local water supplies and promotes thinking in terms of complete watersheds (upstream and downstream cities). Similarly, the one water concept as described in the *Blueprint for OneWater* by the Water Research Foundation (WRF) fully embraces stormwater as a resource and provides a place where all sources of water can be evaluated for their optimal place to achieve economic, environmental, and social benefits (Paulson 2017; U.S. Water Alliance 2016). This new paradigm extends beyond stormwater and envisions an interconnected system that optimizes the tools of treatment, conservation, and recycling (Novotny 2010; Sedlak 2014).

In *The Water-Sustainable City*, Feldman (2017) acknowledges several advancements in Australia that are worth tracking and using as a basis for future work in California. A few observations on Australian experiences are:

- The lessons from Australian cities (e.g., Melbourne) are applicable to some California cities due to similar climate and limited groundwater resources.
- Treated stormwater is being studied as a drinking water source in Australia (McArdle et al. 2011)

Even as the benefits of stormwater capture are intuitive and widely supported by the new paradigm, barriers that are impeding the development, permitting, design, and funding of capture and use projects will have to be addressed to realize the benefits of capture and use. Some barriers, such as market pricing, will require collaboration well beyond the traditional stormwater industry, underscoring the importance of advocating for stormwater and urban runoff in particular as an important component of the development of a diversified water portfolio in California.

2.3 Crafting Agency Partnerships for Managing Stormwater as a Resource

Urban water management in California, like many municipal functions, is highly fragmented (Ostrom 1961; Ostrom 1962). A diversity of organizations, including municipal utilities, investor-owned utilities regulated by state agencies, private non-profit water companies, special purpose districts, and county districts, all provide aspects of urban water services. These organizations have funding sources that vary by duty and geography, but common funding sources are special taxes, utility fees, and bonds. Assembling projects and funding streams in this highly complex environment is a constant challenge for integrative water management in California.

Overlapping and disjointed missions are in part a result of diverging national laws and practices regarding water supply and quality that have origins in how, historically, governments came to manage water (Feldman 2017). Additionally, water supply, flood control, and wastewater infrastructure evolved in different time periods, so the entities charged with these functions were usually different (Tarr 1984; Melosi 2011). The separation of these authorities can lead to cost analysis that does not consider the total benefits that could be realized if all services were considered together. Non-government organizations and watershed groups should also be identified for project collaboration. EPA's "Surf Your Watershed" can be used to identify citizen-based groups within a particular watershed (https://cfpub.epa.gov/surf/locate/index.cfm). Institutional barriers to collaboration among public services will be explored later in this report. Figure 1 provides an example of a water supply system that integrates stormwater into surface water supply resource instead of discharging directly to the river. While this is theoretically possible, it would require a re-evaluation of operating permits (CA HSC 116550) in order to allow stormwater capture as source water for a water treatment plant.

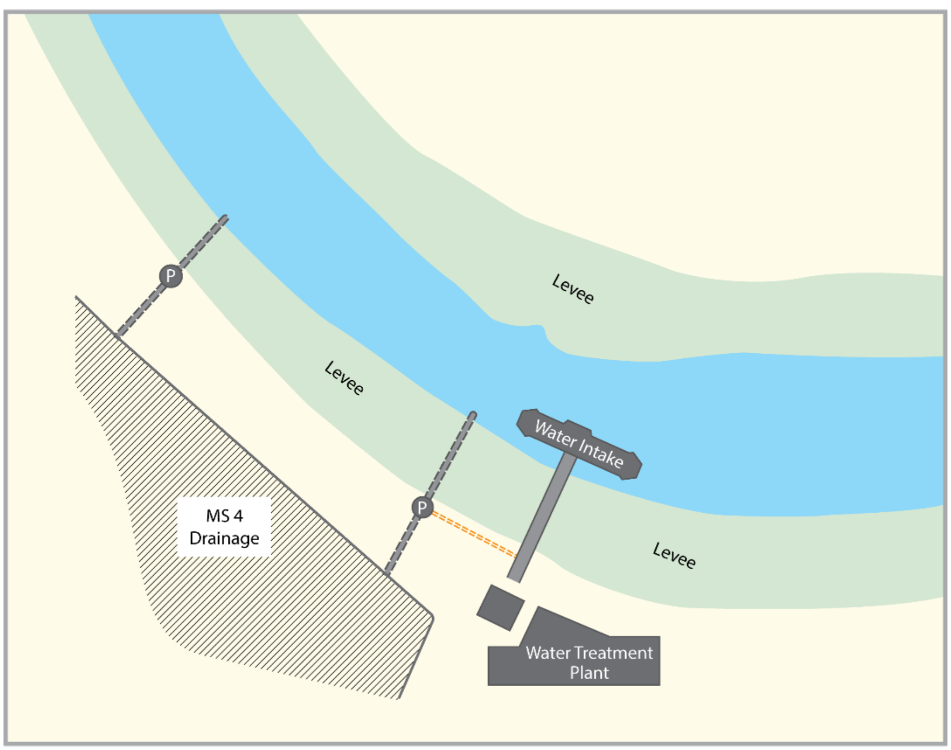


Figure 1: Stormwater Pump Station with a Traditional High-Flow Outlet to the Receiving Water and a Low-Flow Diversion to a Municipal Water Supply Treatment Plant

In addition, other municipal agencies outside of the water sector can contribute to stormwater management. For example, transportation may be the most important companion infrastructure for runoff management because transportation infrastructure footprints often overlay or directly contribute to stormwater drainage infrastructure. Energy and communications infrastructure also hold relatively untapped potential for multiple-benefit projects, though this is the one area where substantial technological questions must still be addressed, such as integration of stormwater capture infrastructure with other utilities and new infrastructure as discussed in later sections. Many of the case studies explored later in this report take advantage of park and recreation facilities. Figure 2 illustrates a park facility that captures stormwater from an industrial area and uses that runoff for irrigation purposes. An infiltration basin is also shown capturing runoff from a nearby neighborhood to promote groundwater recharge. Figure 3 illustrates shared infrastructure with transportation, buildings, and utilities

Figure 2: Parks and Recreation Capture and Use Facility

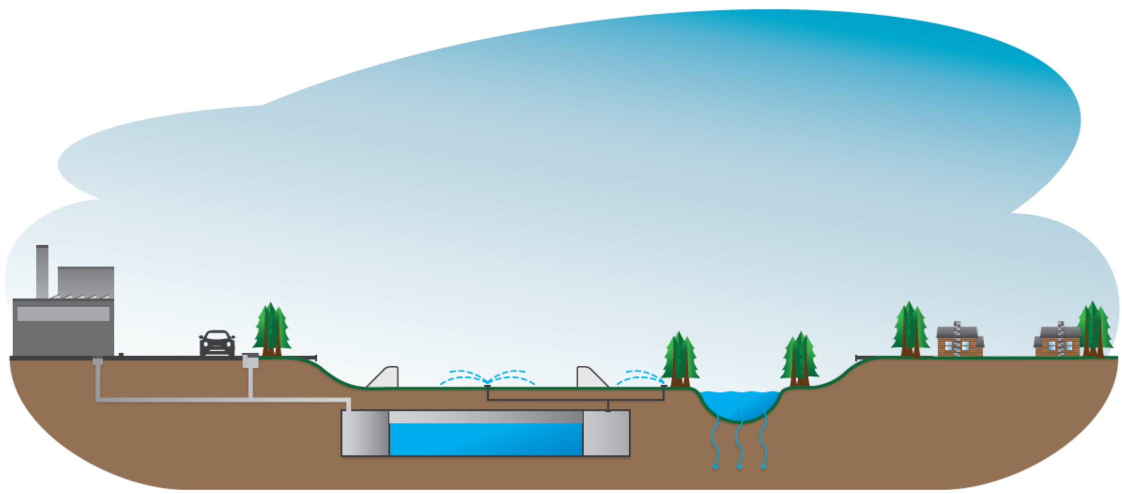
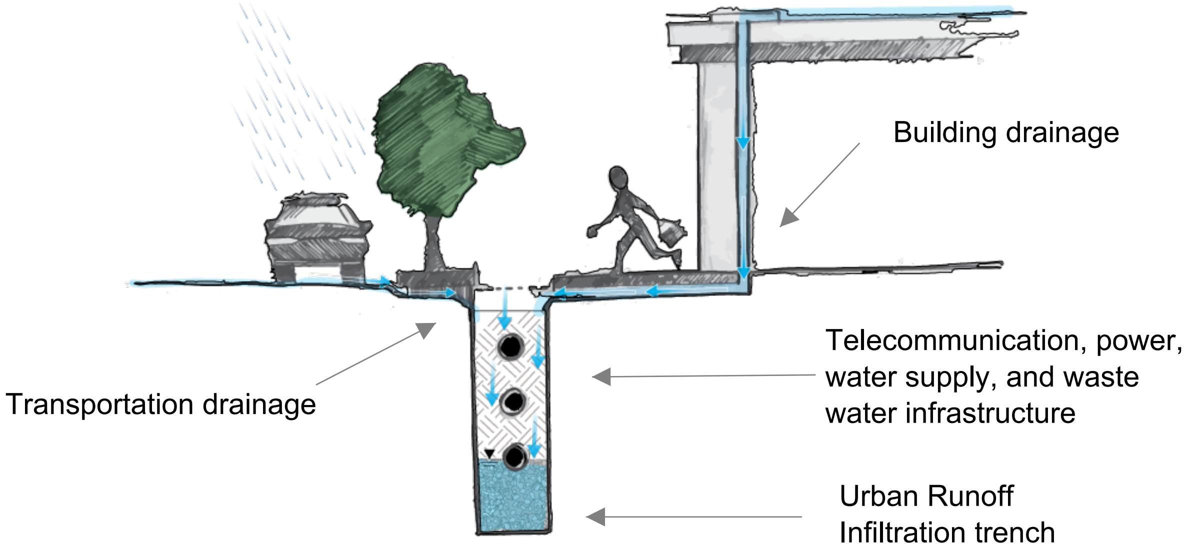


Figure 3: Shared Utility, Transportation, and Building Infrastructure



Agencies and Organizations Involved in Managing Stormwater

Public agencies and professional associations that may lead or advocate for certain projects are described below. This list is meant to be detailed, but not exhaustive. Other agencies, associations, and non-governmental organizations (NGOs) may be valuable partners in increasing capture and use. Many of these organizations have developed resources that specifically support capture and use projects. Links to additional resources identified in this report are found in Section 3.2. Additional information regarding the barriers, drivers, potential projects for statewide solutions, and lead agencies is included in Table 2.

Government Agencies

State Water Resources Control Board and Regional Water Quality Control Boards
The State Water Boards can facilitate capture and use projects by developing and establishing a monetary value of stormwater in volumetric terms as an additional source of local water supply as well as its value to water quality. This aligns with project 1d of the Phase II STORMS stormwater strategy and will assist with the evaluation of multiple-benefit analyses associated with capture and use projects. Along with establishing a value of stormwater, providing guidance for identifying the multiple benefits of projects and linking those benefits with potential funding sources (including local) is essential to implementing stormwater capture and use projects. Streamlining the implementation of capture and use projects would ultimately promote the enhancement, preservation, and restoration of California's water resources for both consumption and environmental purposes. Some barriers and applicable projects that might be addressed by the State Water Board are described in greater detail in Table 2 (See 1 A, 2, 4 A & B, 5 A, 7, 8, 12 A & B, 13 A & B, 14, 16, 18, 21, and 22).

California Department of Water Resources
The Department of Water Resources (DWR) is responsible for managing and protecting California's water resources. In its planning function, DWR provides the state's water plan and IRWM strategic plan, as well as guidance on sustainable groundwater management. DWR evaluates current and future water use and availability, including development of new water supply sources. For example, retrofitting flood control basins provides an ideal opportunity to capture stormwater. DWR can facilitate capture and use projects by developing guidance for evaluation of retrofitting flood control basins for capture and use. In addition, DWR can facilitate the development of statewide requirements and guidance on using a triple bottom line analysis that assesses environmental costs and benefits of various water supply sources using a standardized method. State well standards could also be revised to accommodate capture and use projects by permitting the construction of drywells within drainage areas that may be prone to flooding. DWR is also required to update the Model Water Efficient Landscape Ordinance (MWELO) every three years with the next update effective in 2020. This regulation is composed of minimum standards used in design to create landscapes that more effectively manage stormwater flows by infiltration through healthy soils, interception by plants, and erosion control from the application of mulch and proper grading practices. Some barriers and applicable projects that might be addressed by DWR are described in greater detail in Table 2 (See 8, 10, 13 D, 20, 22).

U.S. Environmental Protection Agency

The Environmental Protection Agency (EPA) has a vital role to play in the implementation of capture and use projects by developing guidance on outreach to communicate a triple bottom line approach that promotes community ownership of water project decisions. The goal of this outreach is to educate and actively engage communities when implementing capture and use projects. The EPA can also assist with the development of funding criteria for multiple-benefit projects that will increase water supply, improve water quality, and provide public health gains. Some barriers and applicable projects that might be addressed by the agency are described in greater detail in Table 2 (See 2, 4 A, 5 B, 16, 17, 23).

California Governor's Office of Planning and Research

The Governor's Office of Planning and Research (OPR) can facilitate the implementation of capture and use projects by developing guidance for stormwater capture and use planning for developers and planners. This guidance can then be adopted into city and county ordinances governing entitlement. Streamlining capture and use projects aligns with OPR's function of coordinating federal grants for environmental goals as well as coordinating the operation of integrated climate adaption and resiliency programs (http://www.opr.ca.gov/about/). Some barriers and applicable projects that might be addressed by OPR are described in greater detail in Table 2 (See 17, 19).

California Natural Resource Agency

Quantifying multiple environmental benefits can be helpful in justifying diverse funding sources. The California Natural Resource Agency can assist with the development of guidance for performing benefits evaluation, including the value of reducing demand for out-of-basin water sources that have associated environmental impacts. In addition to reduced environmental impacts, reduced energy consumption to deliver water should also be acknowledged and considered in the analysis. Early involvement of the agency will promote the protection and responsible management of the state's natural resources. Some barriers and applicable projects that might be addressed by the agency are described in greater detail in Table 2 (See 20).

California Public Utilities Commission

The California Public Utilities Commission (CPUC) oversees investor-owned water supply utilities and serves the public interest by protecting consumers and ensuring the provision of safe, reliable utility service and infrastructure at just and reasonable rates, with a commitment to environmental enhancement. The CPUC can assist with the implementation of capture and use projects by helping quantify the costs associated with a variety of water sources (desalination, recycling, traditional, etc.) from publicly-regulated investor-owned utilities. To efficiently perform a triple bottom line analysis, reductions in energy consumption associated with transporting out-of-basin sources should be considered. Some barriers and applicable projects that might be addressed by this commission are described in Table 2 (See 1 A).

Federal Highway Administration—Office of Planning, Environment, and Realty Research

Transportation projects provide an opportunity to implement capture and use projects within the public right of way. The Federal Highway Administration (FHWA) has an office that is committed to conducting and supporting research that strengthens transportation decision-making and promotes efficiency while protecting and enhancing our communities and the environment (https://www.fhwa.dot.gov). FHWA can facilitate education and outreach for transportation officials and legislators to incorporate water funding sources into transportation funding. FHWA can help integrate water capture infrastructure within utilities and other infrastructure by providing technical guidance and outreach. Some barriers and applicable projects that might be addressed by the administration are described in greater detail in Table 2 (See 3, 6, 23).

Groundwater Sustainability Agencies
Local agencies are required to submit Groundwater Sustainability Agency (GSA) formation notifications to DWR under the Sustainable Groundwater Management Act (SGMA). The formation of locally-controlled GSAs is required in the State's high and medium priority groundwater basins and subbasins. A GSA is responsible for developing and implementing a groundwater sustainability plan (GSP) to meet the sustainable goal of the basin to ensure that it is operated within its sustainable yield (http://www.water.ca.gov/groundwater/sgm). SGMA may encourage GSAs to implement capture and use projects by fostering stormwater recharge partnerships using MS4 runoff. Some barriers and applicable projects that might be addressed by these organizations are described in Table 2 (See 18, 22).

Municipal Code and Building Departments
Municipal code requires newly developed and redeveloped areas to comply with certain stormwater treatment and infiltration requirements. In California, typically the requirement is to treat runoff from either the one inch, twenty-four hour rain event or the 85th percentile, twenty-four hour rain event. In some areas such as the city of Los Angeles, the trend has been to move towards complete retention of stormwater runoff on-site. This trend promotes increased capture of stormwater that can then be put towards a variety of uses.

Integrated Regional Water Management Groups
Integrated Regional Water Management Groups promote collaboration on a regional scale to identify and implement water management solutions that increase regional self-reliance, reduce conflict, and manage water to achieve social, environmental, and economic objectives. Stormwater planning is a critical component to the Integrated Regional Watershed Management Plans (IRWMP) processes. To improve collaboration among local agencies and nongovernmental organizations throughout a watershed, Stormwater Resource Plans (SWRPs) could be legislatively required. Currently SWRPs are only required for receiving Prop 1 funding. This could push localities to consider how to better utilize stormwater as a resource.

Regional Stormwater Coalitions and Joint Powers Authorities
Regional stormwater coalitions and joint powers authorities (JPAs) promote regional consistency for stormwater management and work to more efficiently manage public resources. The Bay Area Stormwater Management Agencies Association (BASMAA) is an example of a regional stormwater coalition of nine local governments that was formed in response to the NPDES permitting program to promote regional consistency and efficient allocation of resources. JPAs like Monterey One Water and Southern California Coastal Water Research Project (SCCWRP) provide another institutional pathway for regional collaboration and stormwater planning that can evaluate and potentially coordinate the implementation of capture and use projects.

California Department of Fish and Wildlife
Implementing stormwater capture and use projects can result in stream dewatering. The California Department of Fish and Wildlife (CDFW) can provide insight and investigate circumstances where stream dewatering may be a constraint worthy of site-specific analysis. CDFW can develop guidance regarding the scale of projects that would require a study as well as provide a list of additional factors to consider that would trigger the need for further analysis. Early involvement by CDFW in the CEQA process promotes interagency coordination with the goal of minimizing the potential for negative impacts to habitats necessary for the state's diverse fish, wildlife, and plant resources. Some barriers and applicable projects that might be addressed by the department are described in greater detail in Table 2 (See 12 C).

Non-Governmental and Industry Organizations

American Institute of Architects
The American Institute of Architects (AIA) can educate architects about capture and use. Architects need to integrate capture and use into concept plans rather than attempting to find sufficient space for capture and use later in the design process. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 4 A).

American Association of State Highway Transportation Officials
Roadway infrastructure can be challenging to integrate with stormwater infrastructure. The American Association of State Highway Transportation Officials (AASHTO) can work to educate the public and key decision makers about the role transportation projects can play in capture and use projects. AASHTO can also lead education and outreach to transportation officials and legislators to incorporate water infrastructure and water funding sources into transportation funding. This educational outreach is essential to streamlining the implementation of multiple-benefit capture and use projects. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 3, 6).

American Planning Association
The American Planning Association (APA) advocates for "excellence in planning, promoting education and citizen empowerment, and providing its members with the tools and support necessary to meet the challenges of growth and change." APA can provide guidance for stormwater capture and use planning to developers and municipal planners, which can be adopted into city and county ordinances. The association could also provide education and outreach about integrating water capture infrastructure into transportation projects. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 17, 19).

American Public Works Association
The American Public Works Association (APWA) serves professionals from local, county, state, federal, and private sector backgrounds who work in all aspects of public works projects focused on positively impacting the quality of life in the communities they serve (http://www.apwa.net). APWA has been a leader in the development of guidance on identification of the multiple benefits associated with projects via the Envision™ program. As such, APWA is well suited to continue to help advocate and train in the use of a triple bottom

line approach that will ultimately increase community ownership of water project decisions. Some barriers and applicable projects that might be addressed by the association are described in greater detail in Table 2 (See 1 B, 4 A, 5 B, 10, 16, 19, 23).

American Rainwater Catchment Systems Association

Storing water for extended periods of time can impose a barrier to capture and use projects, particularly when oxygen levels decrease, requiring additional treatment costs. The American Rainwater Catchment Systems Association (ARCSA) is committed to promoting the advancement of rainwater collection and could provide guidance for storage of captured water for irrigation and identification of innovative technologies to expand storage times. In addition, the association could assist local departments of public health in applying appropriate requirements associated with using captured stormwater. Some barriers and applicable projects that might be addressed by this association are described in greater detail in Table 2 (See 9, 21).

American Society of Civil Engineers

Technical guidance regarding the implementation of capture and use systems is needed. The American Society of Civil Engineers (ASCE) and its Environmental and Water Resources Institute (EWRI) focuses on advancing water resources and environmental solutions to achieve a sustainable future (http://www.asce.org/environmental-and-water-resources-engineering/environmental-and-water-resources-institute/). ASCE can lead projects to develop technical guidance on capture and use projects that ultimately align with the organization's efforts to support sustainable infrastructure and technologies. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 4 A, 21).

American Water Works Association

The American Water Works Association (AWWA) is an international nonprofit, scientific, and educational society dedicated to providing total water solutions aimed at assuring the effective management of water. AWWA offers education to water professionals and is an advocate for safe and sustainable water. For more than 100 years the association has developed technical standards for minimum requirements, materials, and equipment and practices used in water treatment supply (https://www.awwa.org/publications). AWWA may also be suited to identify innovative technologies to expand storage times. Some barriers and applicable projects that might be addressed by this group are described in greater detail in Table 2 (See 9, 14, 16, 21).

Association of California Water Agencies

The Association of California Water Agencies (ACWA) is the largest statewide coalition of public water agencies in the country. The mission of the agency is to help members promote the development, management, and use of good quality water at the lowest practical cost and in an environmentally responsible manner. ACWA can facilitate the implementation of capture and use projects by developing a standard method for valuing captured stormwater that could be applied throughout the state. Some barriers and applicable projects that might be addressed by this association are described in Table 2 (See 1 A).

California Stormwater Quality Association
The California Stormwater Quality Association (CASQA) is an organization that can leverage expertise throughout the stormwater sector by addressing stormwater issues within the subcommittees of the association. These subcommittees can develop problem statements and advocate for funding. CASQA can also collaborate with a number of agencies and organizations to promote capture and use projects. For example, CASQA can coordinate with the Governor's Office for Planning and Research to develop guidance for stormwater capture and use planning for developers and municipal planners to be adopted into city and county ordinances governing entitlement. CASQA can also work with the State Water Board and DWR to provide training to better understand natural hydrologic and hydrogeomorphic processes associated with drywells. These projects all align with the association's vision to advance stormwater quality management through collaboration, education, and implementation guidance. Some barriers and applicable projects that might be addressed by this association are described in Table 2 (See 7, 13 C, 16, 17).

Local Government Commission
The local Government Commission (LGC) has published Ahwahnee Water Principles that outlines stewardship actions that cities and counties can take to reduce costs and improve the reliability and quality of water resources. These principles include incorporating water holding areas such as creek beds, ponds, and cisterns into urban landscapes as well as designing landscapes to reduce water demand, retain runoff, decrease flooding, and recharge groundwater. Additional information can be found via the Urban Stormwater Management Fact Sheet. The LGC also educates decision makers about opportunities for stormwater capture and use. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 5).

National Association of City Transportation Officials
The National Association of City Transportation Officials (NACTO) is focused on providing transportation options that are safe, sustainable and accessible. The association provides an Urban Street Stormwater Guide that offers guidance for municipalities to incorporate sustainable stormwater management practices to support ecosystems with human land use and development. NACTO is focusing on integrating green stormwater infrastructure into the right-of-way, which requires a holistic vision for sustainable urban design (https://nacto.org). The association can continue to educate city transportation officials regarding stormwater management and capture as well as opportunities to implement capture and use projects. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 3, 6).

National Association of Flood and Stormwater Management Agencies
The National Association of Flood and Stormwater Management Agencies (NAFSMA) is an organization of public agencies whose mission is to encourage technologies and conduct education programs that facilitate and enhance the achievement of the public service functions of its members. This organization appears to provide an ideal link between stormwater and flood control agencies. NAFSMA could collaborate with stormwater and flood control agencies to develop guidance for evaluation and design of retrofitting flood control basins for capture and use. Some barriers and applicable projects that might be addressed by this association are described in greater detail in Table 2 (See 8).

National Blue Ribbon Commission for Onsite Non-Potable Water Systems
To assist local departments of public health in applying appropriate requirements associated with using captured stormwater, treatment requirements that do not require Title 22 could be adopted for all captured stormwater exclusively using existing, unused purple pipe (no comingling with recycled water). The National Blue Ribbon Commission for Onsite Non-Potable Water Systems could assist with the adoption of these requirements that would streamline the implementation of capture and use projects and align with the commission's mission of advancing best management systems to support the use of onsite non-potable water systems within individual buildings or at the local scale. Some barriers and applicable projects that might be addressed by this commission are described in Table 2 (See 14).

National Municipal Stormwater Alliance
The National Municipal Stormwater Alliance (NMSA) vision statement focuses on enabling MS4 permittees across the country to develop efficient and effective stormwater programs. As a national organization representing many MS4 programs, NMSA can help promote federal guidance and regulations that provide incentives (or remove disincentives) to capture and use. NMSA can also help with public education and outreach as well as collaborate with FHWA on education and outreach programs to transportation officials and legislators to incorporate water infrastructure into transportation funding. Some barriers and applicable projects that might be addressed by the organization are described in greater detail in Table 2 (See 1 B, 3, 6, 8, 21).

Transportation Research Board, Standing Committees on Stormwater and Landscape and Environmental Design
The Transportation Research Board (TRB) has several committees that could provide valuable education and outreach to transportation officials and legislators to incorporate water infrastructure and water funding sources into transportation funding. The Standing Committee on Stormwater is concerned with the design and construction of transportation-related stormwater facilities to address runoff of pollutants, methods for managing stormwater volume and flow, and methods for improving water supply and stormwater quality (https://map08g.wixsite.com/afb65). The Standing Committee on Landscape and Environmental Design is concerned with design parameters that relate to protecting, conserving, restoring, and enhancing safe, sustainable, and livable transportation systems and facilities and their associated environments (https://sites.google.com/site/trbcommitteeafb40). Some barriers and applicable projects that might be addressed by these committees are described in greater detail in Table 2 (See 3, 6).

Urban Land Institute
The Urban Land Institute (ULI) provides leadership in the responsible use of land and in creating and sustaining thriving communities worldwide (https://uli.org/). ULI can help facilitate capture and use projects by assisting with the development of approaches for valuing stormwater as a resource and outreach associated with educating the public that enhanced water management mechanisms create value by enhancing aesthetics and improving operational efficiency. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 17).

Water Environment Federation/Stormwater Institute

The Water Environment Federation (WEF) and its members have protected public health and the environment since its establishment in 1928. WEF has a diverse membership including scientists, engineers, regulators, academics, utility managers, and other professionals who share the common goal of improving water quality. WEF has developed an initiative for National Stormwater Testing and Evaluation for Products and Practices (STEPP) (http://stormwater.wef.org). This program aims to fill the void created by a lack of national stormwater control measure testing and verification programs. The STEPP process may be adapted to address capture and use verification. Some barriers and applicable projects that might be addressed by this federation are described in greater detail in Table 2 (See 4 A, 21).

Water Environment and Reuse Foundation

The Water Environment and Reuse Foundation (WERF) is a nonprofit that conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids (http://www.werf.org). WERF has sponsored projects that are beneficial to capture and use by developing a "First Steps" spreadsheet-based tool to help utilities evaluate the costs and benefits of diversifying their overall water management portfolio. Additional projects led by the foundation include an effort to assess the risks, costs, and benefits of using stormwater to enhance local water supplies. This analysis includes identifying co-benefits and performing a triple bottom line analysis. A life-cycle cost analysis tool was developed as a part of this project to guide decision makers in the selection of stormwater infrastructure alternatives. WERF can continue to advocate for capture and use projects by developing other tools to assist decision makers and raise awareness regarding capture and use opportunities. Some barriers and applicable projects that might be addressed by this foundation are described in greater detail in Table 2 (See 4 A, 21).

Water Foundation

The Water Foundation is focused on enabling new and innovative approaches to meet collective water needs. The Foundation has been an advocate for SB 231, which would allow local governments to levy taxes for purposes of stormwater management projects. One of the foundation's goals is to pool and align philanthropic funding to support groups that are finding smart ways to improve water management. Building bridges among diverse leaders and catalyzing partnerships to develop and implement projects while helping shape collaborations into lasting networks would be beneficial for capture and use projects. Some barriers and applicable projects that might be addressed by this foundation are described in Table 2 (See 7).

2.4 Building Coalitions at the Municipal Scale

The WEF 2015 Green Infrastructure report identified the variety of stakeholders that should be considered for engagement in community-based stormwater systems planning. These stakeholders are listed in Table 1 and should also be considered for capture and use implementation.

Table 1: Community Stakeholder Engagement

Stakeholders for Engagement in Green Infrastructure Program	
Sewer Council/Commissioners	City Council (as applicable)
City/Municipality Planning Department	County Planning Department (as applicable)
Health Department	Local foundations, grant agencies, etc.
Department of Public Property	Streets Department
Mayor's Office	City Public Works
Drinking Water Utility	City Parks Department
City/County Roads Department	State Department of Transportation
Telecom, Transit, Gas and Electric Utilities	Local universities
Economic Development Council/Agency	Local developers
Regional Coordination/Planning Agencies (as applicable)	Regional Transportation Planning Agencies
Local Environmental Groups	Local EPA or Department of Environmental Protection
Local watershed/waterkeeper/conservation groups	Experts from local and national consultants
Local development engineers/architects	Local School Boards
Urban Development/Housing Authority	Local landscapers and arborists
Local businesses/retail owners	Members of the general public not directly involved with water issues

3 Capture and Use Tools

The appropriate tools for implementing capture and use necessarily depend on the definition of capture and use. The next section offers a definition, followed by an introduction to the tools.

3.1 Defining Capture and Use

To date, capture and use has been focused on enhancing water supply through either capture and storage in tanks for direct use or recharge of aquifers (NAS 2016). But this report outlines a broader definition. Because the State Water Board aims to support valuing stormwater as a resource and to encourage active capture of urban runoff, a definition of urban runoff capture and use was developed: the intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems. This new, broader definition requires additional explanation.

Definition: Capture and Use

The intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems.

"Intentional collection" is used to differentiate intended actions to enhance use of runoff from other passive approaches. For instance, intentional actions may include infiltration basins or green streets that capture and recharge stormwater, while passive approaches include preserving open space to maintain natural hydrologic function. While laudable, these passive approaches do not change the urban runoff water balance to increase the use of stormwater. Intentional collection requires infrastructure to increase capture and use in both retrofit of existing and building of future urban development.

The term "urban runoff" is used because it includes both urban stormwater and urban dry weather flows, and both have been undervalued resources. Dry and wet weather runoff also share common barriers and they often benefit from the same capture and use infrastructure.

Capture and use encompasses at least one of three actions: augmenting surface water supply, recharging groundwater, or supporting ecosystems.

To augment surface water supplies—Surface water supplies are typically managed through controlled infrastructure at many scales, from rain barrels to statewide distribution systems. The collected water is used to satisfy a variety of water demands, such as indoor and outdoor non-potable, potable, industrial, and agricultural. Capture and use can augment these supplies by direct injection or in lieu augmentation where some of the water demand is offset by separate stormwater surface water systems (e.g., rain barrels). Where LID is used in place of planned landscaping, the amount of urban runoff used by vegetation in lieu of other irrigation water supply could also be considered an in lieu augmentation of surface water supplies. The term "surface" is used to distinguish these supplies from aquifer supplies, so, for example, a subsurface cistern would still be considered a surface water supply system. Use of urban runoff is consistent with the goals of the California Water Plan, which endorses stormwater as a water supply source that could improve supply reliability (DWR 2013).

To recharge groundwater—Recharging groundwater promotes the movement of runoff to aquifers for reasons including, but not limited to, preventing seawater intrusion and subsidence, fortifying supply, and sustaining surface water habitats. Groundwater recharge can support surface water habitats by maintaining baseflow to surface waters. In this way, groundwater recharge can also support ecosystems.

To support ecosystems—Capture and use can support ecosystem functions and help maintain and restore stream, wetland, and estuary habitats for species of management concern. The role of capture and use for ecosystem support is best achieved through a watershed approach that recognizes the importance of water and sediment movement, infiltration, and groundwater recharge and discharge for supporting ecosystem processes and habitat. The state legislature affirmed the importance of watersheds in providing clean water in AB 2480, which recognizes watersheds as part of the California water system. Post-construction standards in some regions also embrace the premise of preserving or restoring existing watershed processes (Central Coast Regional Water Board 2013). Achieving these goals can be challenging in watersheds that have been altered by urban or agricultural land uses. In these cases, the concept of "environmental flows" can provide an approach to balance potentially competing goals for managing runoff. Environmental flows are defined as "the magnitude, timing, duration, rate of change, and frequency of flows and associated water levels necessary to sustain the biological composition, ecological function, and habitat processes within a water body and its margins" (Brisbane Declaration, modified by The Nature Conservancy). This definition focuses on replicating key aspects of the annual hydrograph that are critical to support desired ecological goals, rather than restoring "natural hydrology." Capture and use can be an integral tool for managing environmental flows and replicating key hydrograph features to the benefit of ecosystems (NRC 2008; Walsh and Kunapo 2009). In addition to managing environmental flows, capture and use strategies can support ecosystems by improving water quality through the reduction of pollutant loading to streams and estuaries (Lager and Smith 1974; Tourbier and Westmacott 1981; NURP 1983; Schueler 1987).

The stormwater capture and use definition should not discriminate against stormwater projects based on scale or treatment approach. For example, projects that divert stormwater to the headworks of reclamation plants should be counted as capture and use projects where reclaimed water is put to one of the uses described above. This is also consistent with the One Water philosophy.

Capture and use also supports clean surface water by diversion or sequestration of pollutant loads associated with the captured volume. Runoff volume reduction practices have been widely recognized as a water quality tool (Lager and Smith 1974; Tourbier and Westmacott 1981; NURP 1983; Schueler 1987). These and other benefits of particular capture and use approaches are discussed in Appendix A.

3.2 Tools and Resources

Delivering capture and use infrastructure requires use of structural and non-structural tools. Structural tools include stationary and permanent BMPs that are designed, constructed, and operated to prevent or reduce the discharge of stormwater pollutants and/or prevent or reduce the impact of peak runoff flows.

Structural Tools

Structural stormwater water control measures (SCMs) can be grouped according to scale. Centralized systems typically capture runoff from multiple parcels and decentralized systems typically capture runoff within a single parcel (MWD 2015). SCMs that can be applied at both the parcel level and at a larger neighborhood scale are listed below as both centralized and decentralized. The types, use potential, potential benefits, and factors affecting success are summarized in Appendix A.

- Structural stormwater control measures (SCMs)
  - Centralized (difficult to scale down)
    - Detention Basin (lined and connected to regional use)
    - Detention Basins (unlined for infiltration)
    - Detention Basins with Drywells
    - High-Flow Bypass to Spreading Grounds
    - Wet Basins
  - Centralized/Decentralized (highly scalable)
    - Detention Vault/Cistern (lined for local use)
    - Infiltration Vaults (infiltrators)
    - Infiltration Basins (retention basins)
  - Decentralized (difficult or expensive to scale up)
    - Infiltration Trenches
    - Bed Filter with Infiltrating Underdrain
    - Bioretention Raingarden (underdrain)
    - Bioretention Raingarden (no underdrain)
    - Green Roofs
    - Pervious Pavement
    - Swales, Filter Strips (biofiltration, buffer strips)

Non-structural Tools

Non-structural tools are just as vital to implementing capture and use as the SCMs themselves. The non-structural tools listed below are grouped by valuation, regulation, incentive programs, fiscal, and institutional. Some of these types of tools are interdependent (e.g., funding is required for incentive programs). Also, some tools are not supported by surveyed case studies and literature (e.g., requiring retrofit of private property). The availability or examples of usage of non-structural tools are summarized in Appendix A.

- Non-Structural tools
  - Valuation
    - Cost
    - Support ecosystem function
    - Triple bottom line (economic, environmental, and social valuation)

- Regulation of Private Property
    - Performance standards for new construction and redevelopment (requiring stormwater controls that reflect regional needs such as hydromodification or groundwater deficit)
    - Retrofit requirements on existing developed properties
- Regulation and Local Policy Governing Public Property
    - General plan requirements to assess local water supply feasibility (including urban runoff)
    - New and redevelopment of public infrastructure (requirement for stormwater controls that reflect regional capture and use needs)
    - Retrofit program for existing public development with stormwater controls that reflect regional capture and use needs
    - Requirements regarding growth type, such as density, infill, and zoning, that consider local and regional water resources and needs.
    - Policy of agency coordination, leveraging funds/projects to overcome financial barriers (e.g., transportation, parks, and economic development)
- Incentive Programs
    - Voluntary Offset Program: Property owners place a bid for stormwater capture and use projects to be installed on their property for free, and an amount of money for which they would like to be compensated for accepting these projects on their property. The bids are weighted according to the cost of the project and the amount of environmental benefit it will provide. The bids are ranked according to least cost and largest environmental good. The bids are awarded until the money available is expended.
    - Fast Track Review: Provides a faster permit review process for projects that have incorporated capture and use
- Fiscal
    - Grants for capture and use projects with options for long-term O&M
    - Grants for technical consultation, evaluation, and capacity building/finance planning
    - Triple bottom line guidance for both water and non-water agencies to assess benefits of supporting stormwater capture and use
    - Assessment guidance on marginal cost of capture and use vs. treatment and release
- Institutional
    - Joint Powers Authority (JPA) or Enhanced Infrastructure Financing Districts (EIFDs)

Resources for Capture and Use

In addition to the government agencies and professional organizations listed in Section 2.3, there are a number of organizations that provide resources that may be helpful in public engagement, design, alternatives analysis, benefits quantification, and other aspects of implementing capture and use. The following list includes agency names as well as links to those resources that may assist with advocating for and implementing capture and use projects.

Tools:

- CASQA LID Portal (https://www.casqa.org/resources/california-lid-portal)
- Urban Greening Carbon Sequestration Quantification Tools
    - i-Trees (https://www.itreetools.org/)
    - CTCC (https://www.fs.usda.gov/ccrc/tools/tree-carbon-calculator-ctcc)

Resources:

- City of Philadelphia: "A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds" (https://www.casqa.org/sites/default/files/downloads/stratus_consulting_2009_-_a_triple_bottom_line_assessment.pdf)
- Council for Watershed Health (https://www.watershedhealth.org/)
- ASCE: "Downstream Economic Benefits from Stormwater Management" (http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9496(2004)130:6(498))
- CPUC: "What will be the Cost of Future Sources of Water in California" (http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Production%20costs%20for%20new%20water.pdf)
- Urban Land Institute: "Harvesting the Value of Water" (https://americas.uli.org/wp-content/uploads/sites/125/ULI-Documents/HarvestingtheValueofWater.pdf)
- ASCE: "Integrated Management of Irrigation and Urban Storm-Water Infiltration" (http://ascelibrary.org/doi/pdf/10.1061/(ASCE)0733-9496(2006)132:5(362))
- Institute for Sustainable Infrastructure: Envision valuation tool (http://sustainableinfrastructure.org/envision/)
- Integrated Regional Water Management Publications (http://www.water.ca.gov/irwm/other_resources/publications.cfm)
- LID Center (https://lowimpactdevelopment.org/)
- LIDI Central Coast (https://www.centralcoastlidi.org/)
- Protect Every Drop Partners (http://www.protecteverydrop.com/)
- City of Elk Grove: "Assessing the Risks of Using Dry Wells for Stormwater Management and Groundwater Recharge" (https://www.elkgrovecity.org/UserFiles/Servers/Server_109585/File/Departments/Public%20Works/Drainage/Dry%20Wells/dry-well-doc-01.pdf)
- NRDC and the Pacific Institute: "Stormwater Capture Potential in Urban and Suburban California" (http://pacinst.org/wp-content/uploads/2014/06/ca-water-stormwater.pdf)
- State of California: 2016 California Plumbing Code (https://archive.org/details/gov.ca.bsc.title24.2016.05)
- National Blue Ribbon Commission for Onsite Non-potable Water Systems: "Blueprint for Onsite Water Systems" (http://sfwater.org/modules/showdocument.aspx?documentid=6057)

- Los Angeles Basin Study: The Future of Stormwater Conservation Task 6–Trade-Off Analysis & Opportunities (https://www.usbr.gov/lc/socal/basinstudies/LABasin.html)
- California Department of Public Health: Checklist for Minimizing Vector Production and Stormwater Management Structures (https://www.cdph.ca.gov/Programs/CID/DCDC/CDPH%20Document%20Library/ChecklistforVectorPreventioninBMPs.pdf#search=stormwater; see also Metzger et al 2017)
- Mosquito Vector Control Association of California: How Better Planning and Use of the California Environmental Quality Act Can Prevent Mosquitoes and Vector-Borne Diseases (http://www.mvcac.org/advocacy-and-legislation/resource-materials/)

4 Barriers, Drivers, and Factors Affecting Success

There are a variety of barriers to stormwater capture and use and its implementation in California. A preliminary list of barriers to capture and use was developed by the study team and integrated into a template (see Appendix C) developed to solicit stormwater capture and use case studies throughout California. The solicitation for stormwater capture and use case studies was sent out to the STORMS Project 1a/1b Project Advisory Group (PAG) on October 28, 2016, and the PAG was encouraged to submit case studies and forward the solicitation for case studies to others as well. A template for the case study information was developed and integrated into the solicitation. Although the template included the preliminary list of barriers for respondents to select from and identify barriers specific to their projects, the solicitation also encouraged respondents to identify additional barriers associated with their projects.

Several capture and use case studies were received from the solicitation. Some identified barriers. A subset of the case studies included new or unique barriers encountered in undertaking projects, along with solutions that municipalities used to overcome challenges. These case studies, along with representative examples of types of capture and use projects, are included in Appendix B. The case study survey forms for all of the case studies are provided in Appendix C. Capture and use also has shared barriers with the implementation of green infrastructure. A discussion of these barriers is included in WEF 2014.

Additional barriers to stormwater capture and use were identified based on the experiences of the Technical Advisory Committee (TAC) with stormwater capture and use projects. The TAC and PAG convened on September 19, 2017 to identify additional barriers that were not already captured in the case studies. All identified barriers fell within four general categories:

1) Financing/valuation
2) Education and guidance
3) Institutional and policy-related (including law and regulations)
4) Technological

The need for technical analysis that may be required to address any particular barrier categories should not be confused with the technology barrier category that identifies a lack of engineered/technological solutions. Table 2 describes potential projects to address the barriers identified in each category. The category and barriers are introduced in the following subsections.

4.1 Financing/Valuation

Funding stormwater systems in California presents significant challenges. In 2014, the Public Policy Institute of California (PPIC) gave failing grades for lack of financial investments in both flood and stormwater infrastructure (Hanak et al. 2014). This was corroborated by the case study review, where funding was the most common barrier reported. The maintenance expense of stormwater projects increases the funding gap. Many projects claim that without grant funding, the project would not be viable. Local jurisdictions have been challenged by limited funding mechanisms (Farfsing and Watson 2014). Most recently, California Senate Bill No. 231 (SB 231) may have provided a path forward for MS4s to follow the same standards for setting fees as those applicable to water and sanitary service, addressing barriers to funding presented by the rules of California State Proposition 218 (Prop 218). As of this writing, this legislation has not been tested by municipalities and legal challenges have been promised.

Another funding barrier is “willingness-to-pay” considerations of residents. Residents of urban areas are more willing to pay for stormwater improvements if they are associated with additional environmental benefits such as habitat improvements. For instance, one study suggests that residents of Philadelphia were willing to pay as much as 2.5 times more annually per household for improvements that reduce combined sewer overflows (CSOs) and benefit the environment in some additional way when compared to traditional grey infrastructure improvements (Raucher 2009).

In the absence of broadly assessed benefits for stormwater projects that consider the potential economic, environmental, and social outcomes of projects, many project advocates fail to broadly engage community stakeholders as part of the planning processes. While environmental and economic factors are more readily quantified, California seems to rely on the public engagement process to consider social equity. However, unorganized public input does not always translate into the proper criteria and value weighting from stakeholders. Triple bottom line analysis is one way to organize public engagement around project objectives and promote the proper valuation of economic, environmental, and social benefits. This increases the likelihood of success of capture and use projects in the long run because preferred alternatives have increased community support.

A lack of quantitative analysis of benefits can also miss other funding sources for functions other than stormwater (e.g., urban greening, public safety, transportation). But depending on funding terms and conditions, some of these funding sources (e.g., transportation) do not explicitly allow financing of stormwater quality (or capture) infrastructure, which is a barrier to capture and use projects that will only be financially and politically viable as a multiple-benefit project. In this current year, California Senate Bill No. 1 (SB1) identified environmental mitigation as a function that can be funded, though inclusion of stormwater capture could be more explicit in the bill.

The potential benefits to include in capture and use cost studies are region-specific. Cities searching to maximize regional water supplies and reduce out-of-basin imports can look to include averted costs of water supply in benefit-cost calculations for new stormwater infrastructure. This is especially the case in downstream coastal cities, where maintaining groundwater basins is crucial to prevent adverse impacts of overusing local supplies such as seawater infiltration. Many parts of Southern California, where the cost of purchasing water from large import or wholesale agencies is more expensive (MWD 2015), can include averted costs of water supply in benefit-cost calculations for new stormwater infrastructure as well. Coastal cities also have an incentive to use and reuse as much water as possible from an anthropogenic perspective, as surface water discharges flow to the ocean. Inland and in some northern parts of California, averted costs of water supply are not as significant a driver. The unit cost of fresh water for supply is cheaper, and discharging water to surface water bodies supports aquatic ecosystems and downstream urban and agricultural users. Thus, no single set of benefits for stormwater capture and use will meet all needs for all agencies, but general guidelines about possible benefits are valuable for water utilities in financing studies.

Capture and use proponents need tools to estimate the marginal cost increase of capture and use compared to current treat and release practices. Current regulation requires infrastructure to treat and release stormwater for new development. Treat and release infrastructure is sunk cost due to existing requirements, so costs to enhance that infrastructure to accomplish capture and use should only consider the increase in cost over the treat and release infrastructure. Project proponents will perform a cost/benefit analysis on the additional costs of moving the retained water to the place of demand for water use. For example, a retention basin may achieve hydrologic requirements, but it may not infiltrate to useable aquifers. The addition of drywells would move the water to a point of use. The cost/benefit of the capture and use would only consider the cost of the drywells. Examples of marginal cost analysis of capture and use above current permit requirements for SCM are not available. However, some work has been done comparing LID costs to traditional storm sewer costs (EPA 2007).

Many tools should be considered in overcoming the funding barriers. These tools are explored further in STORMS Project 4b, “Eliminate Barriers to Funding Storm Water Programs and Identify Funding for Storm Water Capture and Use Projects.”

4.2 Education/Guidance

Effective education, ranging from public education to detailed design training for engineers and landscape architects, is essential for successfully promoting capture and use projects. Case studies indicate that technical knowledge for capture and use exists among stormwater professionals; however, dispersing this valuable knowledge and lessons learned among utility managers, NGOs, stormwater professionals, and the general public will help avoid increased costs associated with custom analysis and design work as well as generate community support for projects. If the learning curve for LID is indicative of capture and use (over the last ten years, many talks about lessons learned have been presented at stormwater conferences), many of the barriers to stormwater capture and use may relate to a lack of awareness, understanding, and knowledge transfer by stormwater professionals of existing concepts and tools.

Education and training barriers have been addressed by cities like Santa Monica, who has a well-developed capture and use program (Santa Monica 2014). In this program, the tools described in Section 3.2 were applied at a local level to develop a comprehensive capture and use program. So the only substantial barriers are a lack of will and financing (see comments from City of Santa Monica, Appendix E).

Education and awareness is also needed to identify the purpose of existing regulations, so regulatory interpreters can gain a better understanding of how a particular regulation can potentially hinder the implementation of capture and use projects. Educational efforts can overcome regulatory barriers by either changing the text of a regulation or altering the interpretation of the regulation.

In some watersheds, non-potable water demands are met by water recycling, so there is limited demand for direct use of stormwater. However, captured stormwater could be used to support continued delivery of ecosystem services. This also highlights the importance of developing master plans so that all water within a watershed is used and reused to provide the best triple bottom line outcome. State agencies as well as stormwater organizations such as CASQA will play essential roles in developing a consistent messaging effort for the public regarding capture and use. Additional organizations and potential projects to promote educational efforts are listed in Table 2.

Section 3.2 contains a list of available resources that can be useful for educating various target audiences. A few examples where additional guidance is needed for education efforts include:

- Guidance for the range of retrofit options for existing infrastructure, particularly for flood control facilities.
- Guidance for new centralized capture and use systems.
- Guidance on how to design to local conditions considering soil, instream flows, rainfall, climate, and demand.
- Guidance on storage limitations and treatment requirements for long-term storage to avoid worsening water quality.
- Training on Integrated Water Resource Planning and the one water approach.
- Training on the use of tools for and on the appropriate scale to apply triple bottom line analysis.
- Expand the DWR Water Management Planning Tool to incorporate stormwater infrastructure and analyze stormwater as a supply source.
- Guidance in the use of triple bottom line analysis to identify and evaluate the water source alternatives in the state's integrated watershed plans.
- Educational awareness to overcome perception barriers. Despite national guidance and demonstration sites, skepticism can still remain as a result of only one poorly-installed demonstration site. This can result in a long-term setback in the minds of some decision makers (WEF 2014).

4.3 Institutional/Policy

Laws, regulations, policies, and institutional practices can all pose barriers to stormwater capture and use projects. Laws are created by federal, state, and local agencies. The Clean Water Act is a primary legal driver of stormwater management, and along with associated laws, it affects how stormwater utilities devise programs. Regulations are developed by agencies as part of their stated authorities, which interpret and implement approved legislation. Regulations have the full force of law and can provide more specifics for or potentially fill gaps in legislation. Policies are rules or procedures, often formally adopted through decision-making processes, that govern how participants in an entity (jurisdiction, organization, or private company) must act. Finally, practices are typical modes and standards for operation and may or may not be directly linked to more formalized laws, regulations, and policies. Depending on the origin of a barrier, addressing it can require new legislation, revisions to existing regulations, new processes that promote better collaboration where it is currently limited, or other appropriate fixes.

Each of these drivers (laws, regulations, policies, and practices) that shape organizational and individual decisions can provide a level of guidance regarding what actors must do to comply. But the level of guidance varies widely. These drivers can be restrictive, lenient, or breed uncertainty in decision-making. The absence of direction from one of these drivers, too, can yield uncertainty that presents a barrier to decision-making. There is no standard as to whether greater or less regulatory guidance will remove decision barriers, and often uncertainties related to these drivers can be perceived differently across various levels of government.

For capture and use, barriers fall into a number of general categories. Many barriers relate to institutional collaboration, which is often driven by practices and can be impeded by existing policies or regulations. Other barriers for capture and use exist regarding environmental regulations. Such barriers tend to be more legal and regulatory, but uncertainties in how courts interpret laws often slow innovative decision-making by local jurisdictions. Water rights in California can present specific barriers that connect projects to the complex web of California water laws. Public health requirements, too, can present barriers for capture and use as agencies seek to protect the well-being of urban residents. Public health requirements span laws, regulations, and policies. Regional health agencies can have differing guidance and requirements for the treatment and direct use of captured stormwater. Finally, with all these topics, unintended consequences can ensue from the presence or absence of guidance.

The section below describes these topics— identified through workshops and advisory committee input—and relates them to applicable types of institutional guidance and actions.

Institutional Collaboration

Institutional collaboration in metropolitan and water resources management is an old and on-going challenge. In California, the vast array of water agencies with diverse missions spread across varied geographies means that promoting collaboration outside of typical agency siloes usually requires formalized agreements and innovative institutional practices.

In California, many processes to promote integration and collaboration across water agencies use funding programs to promote agencies working together through better practices. These can have legal roots. For instance, statewide requirements for IRWM planning efforts were first specified by SB 1672 in 2002. In other cases, working groups and agreements form through bottom-up efforts. In general, however, only moderate progress has been made in moving agencies across sectors of water management to collaborate more closely, and this influences procedures for capture and use.

Institutional and policy barriers exist both in the public sector (i.e., water districts and municipalities) and private sector (i.e., development community) for capture and use. Many water agencies operate in their own distinctive “decision space” (supply, treatment, flood control) because water serves a number of functions. Thus, officials have divergent interests and political roles, making coordination and setting of priorities with respect to stormwater difficult and preventing multi-sector assessments of benefits. These divergent interests also impede collaboration on water issues, and integration of regional capture and use projects into a one water approach is lost.

Some specific examples of barriers to capture and use related to institutional collaboration include:

- Water districts and municipalities are not required to collaborate on water supply and capture and use projects. This can either make projects funded solely by stormwater funds cost prohibitive or precludes efficient placement of these facilities within the footprint typically under the control of stormwater agencies. Cooperation must also include mechanisms for sharing costs and cost-savings benefits.
- Integrated water management requirements do not include stormwater as a potential supply source. For instance, Urban Water Management Plans filed by water supply utilities rarely mention stormwater and its capture and use. It is a recommendation to assess stormwater as a potential supply source in urban water management plans but not a requirement. SB 985 requires submittal of stormwater resource plans to IRWMP agencies, however there is no requirement for these agencies to integrate stormwater source potential into the water supply portfolio.
- Water resources (water supply, wastewater, recycled water, stormwater, and drainage) are integrated into developments independently, so sustainable water management with integration of water resources is not achieved.
- As noted earlier, there is no standard method for analyzing the environmental benefits and costs of urban runoff compared to other water sources, so capture and use systems are often undervalued. Projects that provide multiple benefits are not valued more than projects that do not. Stormwater agencies, too, often lack financial mechanisms to combine resources with water and other infrastructure agencies.
- Non-water infrastructure project proponents are not required to consult with water infrastructure proponents for the sake of maximizing social, environmental, and economic benefits.
- Regulations are inconsistent among regional agency jurisdictions, and often constrain or compete with each other.

Barriers to institutional collaboration on capture and use projects can exist across agencies with varying duties or within a hierarchy of agencies at different levels of government. For instance, regional water wholesalers and smaller water retailing member agencies, which create a distribution system for water in a region, can have specified missions and interactions that do not necessarily cover cooperative agreements on stormwater capture and use. Conflicting regulations can exist in adjacent jurisdictions, as well as across different regions of the state. Because urban runoff capture and use is still a fairly new concept in California, there are many opportunities to remove unnecessary barriers and help incentivize and facilitate implementation of these projects at various scales.

Environmental Regulations

Environmental regulations exist to protect habitat, groundwater quality, and other environmental factors that could be impacted by stormwater capture and use projects. The history of developing these laws, such as the Endangered Species Act that has governed habitat conservation and land use for decades, are highly detailed and related regulations have been deliberated through court processes.

Existing regulations and law or the lack thereof can be barriers to capture and use. Some stakeholders see environmental regulations as too restrictive. But policies that are too lenient can result in capture and use projects with unintended negative environmental consequences. In many cases, lack of regulatory interpretations for projects leads to uncertainty. Vague or non-existent policies can create uncertainties that discourage capture and use (e.g., drywells in some California counties). Regulations can add to the costs and timeline of a project, require compliance with law other than that related to stormwater management, or prescribe a process or procedure that must be followed for a project to be implemented.

Some resource policies do not directly regulate capture and use but they can result in unintended consequences that may affect the feasibility of capture and use. For example, conservation demands and the desire to promote independence from imported water is encouraging increased reuse of treated wastewater and capture and use of dry and wet weather runoff. Although desirable from a water conservation perspective, these practices present a management challenge for ecological adaptation and resiliency to climate change. Urban and agricultural development over the past 75–100 years has converted naturally intermittent streams to streams with perennial or near-perennial flow (White and Greer 2006). Some of these "perennialized" streams now support sensitive species or species that may be sensitive to climate change, including some threatened or endangered species, such as the Least Bell's Vireo.

Changes to stormwater regulations designed to reduce pollution associated with urban runoff and desires to recycle treated wastewater for potable and non-potable uses are reducing stream flows to more historical levels. However, these reductions may decrease the resiliency of "naturalized" aquatic-dependent species to climate change effects by making them more vulnerable to the extended drought conditions expected to occur under changing rainfall patterns.

There may also be other environmental tradeoffs or impacts with the implementation of stormwater capture and use projects that are not fully evaluated. A few examples of environmental and human health concerns regarding stormwater capture and use include:

- Excessive capture of stormwater and routing away from the source of precipitation may disrupt local watershed processes and negatively impact desired ecosystems.
- Treatment standards and acceptable technologies for direct, non-potable water use are not established (ongoing work by the National Blue Ribbon Commission for Onsite Non-potable Water Systems will be providing a basis for developing local and statewide standards). In lieu of specific regulation of urban runoff systems, other standards like Title 22, which regulates reclaimed water use, are often applied to stormwater use systems.
- State-accepted frameworks for establishing ecosystem needs—particularly minimum baseflows though some proposed frameworks exist—are lacking (Hamel et al 2013).

Policies, like regulations, can be a barrier to some capture and use projects. However, if they are properly set, these limitations can give capture and use proponents more certainty concerning the impact of capture and use projects. Such certainty may actually increase the implementation of capture and use.

Future policy decisions will need to balance water quality, water supply, and species conservation objectives in light of climate induced changes in rainfall-runoff patterns and societal priorities. A framework to balance these values has yet to be established by the state. Some questions to ask when developing or improving regulation include: Does a regulation preclude capture and reuse? Does a regulation introduce a burdensome process? Does a regulation set up conflicts between programs? Does a regulation raise costs? These barriers are not easily removed because changing a regulation is often a long and difficult process.

Stormwater Permits and Planning

Statewide policies increasingly promote better planning by localities and communities towards use of "stormwater as a resource." This is especially true for arid and semi-arid urban areas that face potential reductions in imported water, as well as municipalities that must build out stormwater infrastructure to meet MS4 permit compliance but are struggling to organize sufficient funds. Stormwater permits and the associated processes to achieve compliance are driven by existing laws and regulations that can have highly restrictive aspects, such as specified receiving water body water quality targets, that complicate regional planning associated with new BMPs and capture and use infrastructure.

Senate Bill 985, California Water Code 10563, and requisite guidelines were assessed as a potential barrier to capture and use. As required in 10563, the purpose of the Storm Water Resource Plan Guidelines (Guidelines) is to establish guidance for public agencies for the development of Storm Water Resource Plans consistent with Water Code sections 10560 et seq. (as amended by Senate Bill 985, Stats. 2014, ch. 555, § 5) (State Water Board 2015A). Water Code section 10563, subdivision (c)(1), requires a Storm Water Resource Plan (Plan) as a condition of receiving funds for storm water and dry weather runoff capture projects from any bond approved by voters after January 2014. This is clearly a barrier to capture and use projects as it introduces additional steps to obtaining funding. This requirement applies to Proposition 1 (Prop 1). Prop 1 Guidelines further apply the requirement for a storm water resource plan to all stormwater projects, except those projects using funds that rolled over from funding sources that predate SB 985 (State Water Board 2015B). Prop 1 funding sought to mitigate this barrier by allowing funding for development of storm water resource plans (SWRPs), but this still requires time and effort to develop these plans. On the positive side, the effort to prepare SWRPs may be raising awareness of the benefits of capture and use such that decision makers may prefer them over traditional SCMs. The benefits evaluation requirements in a SWRP may also increase the quality of proposed projects. These positive effects could not be quantified or verified. In the short term, SB 985 appears to be a barrier to individual capture and use projects but it may encourage an increase in overall implementation of capture and use.

Many agency decisions, too, regarding MS4 permit compliance can impose barriers to capture and use. For instance, varied MS4 permit post-construction requirements among Regional Water Boards and the statewide NPDES permits makes creating statewide training programs and design guidelines difficult. In addition, the application of receiving water limitations (RWL) to stormwater conveyances, which have been determined in some cases to be so-called "waters of the US," may inhibit using the stormwater conveyance systems to convey stormwater to regional stormwater capture and use systems. The application of RWLs to the conveyance would require treatment to RWL standards prior to discharge to those conveyances. This increases treatment costs and may require treatment systems or capture and use infrastructure in places that are not cost-optimal. Finally, there is a lack of state regulations directing the inclusion of stormwater as a potential supply source as a condition of entitlement in general plans.

In many parts of the state, significant uncertainties exist regarding regulatory barriers for particular BMPs that can inhibit capture and use projects. For instance, many groundwater managers are cautious with infiltration technologies, especially those designed to connect land surfaces and drinking water aquifers through rapid conveyance. In particular, drywell systems for capture and deep infiltration of stormwater are not used in Northern California even though in Southern California there are many examples of drywells being implemented for this application. Implementation does vary by county and is not necessarily related to north-south groupings. Counties can be reluctant to allow drywell infiltration technologies unless pretreatment is used to meet existing groundwater quality levels. In some areas, drywells are restricted for certain land uses that are associated with a higher risk for groundwater contamination. This issue has been identified in verbal feedback during local outreach presentations as impeding drywell implementation. Similarly, some counties are concerned that the Porter-Cologne Act (Section 13382) requires a waste discharge permit for the implementation of injection wells, of which drywells seem to be included (Section 13051). While a waiver program is allowed (Section 13264), examples of waivers could not be found in the case studies.

As a final example of the disconnect between potential outcomes of planning processes and actual practices, while technologies have been successfully used internationally for direct use of urban runoff (Feldman 2017), a lack of state-approved testing or verification protocol may be limiting use of these technologies. Substantial progress has been made by the National Blue Ribbon Commission for Onsite Non-potable Water Systems. This work is ongoing and should be consulted for the latest guidelines that may be useful in establishing performance criteria for a testing and verification program.

Water Rights

Water rights in California are detailed and complex. They influence many aspects of water management, from decisions on diversions to actions regarding statewide conveyance. For stormwater, a potential legal impediment to capture and use projects is the lack of clarity around when and to what extent water rights are implicated in stormwater capture projects. Typically, a water right is needed whenever surface waters are diverted and applied to beneficial use. (Wat. Code, §§ 1200 et seq.; Cal. Code Regs., tit. 23, §§ 650 et seq.) In general, an entity capturing fleeting, ephemeral flows of stormwater and slowing down, diverting, treating, or percolating such water for flood control or water quality protection is not exercising a surface water right. However, if the water is subsequently put to a beneficial use, such as irrigation, water rights may be implicated. Water right determinations are thus fact-specific.

Where a water right permit is required for a stormwater capture project, the Division of Water Right's temporary water right permit program may be utilized to facilitate a streamlined and expedited process for permitting of the project. As part of the efforts to address emergency flood control measures in 2017, Governor Brown's Executive Order B-39-17 directs the State Water Board to prioritize temporary water right permits for projects that enhance the ability of a local or state agency to capture wet weather high runoff events for local storage or recharge. The Executive Order suspends the California Environmental Quality Act (CEQA) provisions for State Water Board actions on these types of temporary permits, allows for an expedited review process, and substantially reduces application-filing fees.

A legal constraint to stormwater use in the form of rainwater capture systems has been previously addressed through legislation. The Rainwater Capture Act of 2012 clarified that use of rainwater collected from rooftops does not require a water right permit from the State Water Board (Wat. Code §§ 10570 et seq). The act defines rainwater as "precipitation on any public or private parcel that has not entered an offsite storm drain system or channel, a flood control channel, or any other stream channel and not previously been put to beneficial use" (Wat. Code, § 10573). For these particular types of projects, the legislation removed the fear of downstream claims or the expense of checking for impacts on downstream rights. For all other types of stormwater capture and use projects, a water right may be required.

4.4 Technology

Technology was not reported as a limiting factor in the ability to implement stormwater capture and use case study projects. However, a particular strategy that has not been attempted is integrating capture and use with other underground utilities in a high-density urban environment where space for traditional capture and use is not available. Integration of stormwater systems with other utilities has unknown technological requirements to protect the utilities (e.g., telecom infrastructure) or to avoid health or environmental impacts (e.g., sanitary sewer and potable water infrastructure).

4.5 Potential Statewide Solutions

Integrated regional water management plans (IRWMPs) codify watershed-scale planning processes to encourage broad agency partnerships for improved water resources management. For urbanized watersheds, stormwater planning is a critical component to IRWMP processes. Owners and operators of municipal separate storm sewer systems (MS4s) must be included in the development of IRWMPs. Moreover, existing enhanced watershed management plans (EWMPs) in Southern California and stormwater resource plans (SWRPs) in other parts of the state are pushing localities to consider how to better use stormwater as a resource.

In addition, public agencies are required to develop SWRPs, or functionally equivalent plans, as a condition of receiving Prop 1 grant funds for stormwater and dry weather runoff capture projects. To further improve collaboration among local agencies and nongovernmental organizations throughout a watershed, SWRPs could be legislatively required outside of applying for grant funds as well. However, because IRWMPs are not required to integrate information from SWRPs this approach may not have the intended outcome. Consequently, updating IRWMP requirements may be a more effective solution to integrating capture and use into regional plans and improving collaboration among organizations.

Table 2 is a matrix of different barriers to urban runoff capture and use. Although not exhaustive, the matrix identifies specific barriers in each category that were identified either through an analysis of the submitted case studies or through the project experiences of the study team. Experience, though anecdotal, provides critical insight into barriers because much of the experience in failed capture and use concepts is not well-documented. A survey across MS4s may yield quantifiable results, but that was outside the scope of this study.

Included in the matrix are drivers for the identified barriers as well as factors for success in overcoming the identified barriers. Additionally, potential solutions that could be implemented on a statewide level to help remove the specific identified barriers are outlined.

The barriers, and efforts to address them, follow the four broad categories previously discussed: financing/valuation, education/guidance, institutional/policy (including regulatory), and technology. Many of the efforts to address a barrier in a project will apply to more than one category (e.g., every solution will likely involve education and training).

Table 2: Capture and Use Barriers Matrix

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
Financing/Valuation					
1. Projects infeasible without augmentation from temporary funding sources (e.g., grants, local bond measures)	1. Lack of value of stormwater as a resource 2. Lack of start-up funds to perform triple bottom line (large projects) or minimum alternatives analysis (small projects) 3. Stormwater valuation seems impossible without addressing the undervaluation of other water sources due to federal and state subsidies of the surface water capture and distribution systems	1. Lack of implementation of stormwater capture and use projects 2. Lack of ability to identify multiple benefits through a triple bottom line analysis or minimum alternatives analysis	1. Identification of multiple benefits and of other sources of funding (e.g., the Caltrans fund has provided startup costs for some projects that support TMDL compliance—see Appendix D for funding criteria)	A. Approaches to the valuation of stormwater as a resource B. Guidance on identification of multiple benefits of projects and associated funding sources C. Providing project development money for alternatives analysis. Could require reasonable assurance analysis (RAA) as a prerequisite to help ensure work products are useful D. Guidance on how to plan/develop projects considering partnerships and site specific conditions (e.g., LADWP Capture Master Plan provides example of leveraging ongoing projects that benefit stormwater	A. Phase II STORMS Project 1d; Related STORMS project: Eliminate Barriers to Funding Stormwater Programs and Identify Funding for Stormwater Capture and Use Projects B. APWA, NMSA, WERF etc. C. Legislature D. APWA, CASQA, NAFSMA E. CUWA, APWA, State Water Board

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
	4. Urban stormwater capture costs vary greatly based on site-specific conditions—such as infrastructure requirements to transfer, treat, and store the supply—and local hydrology including options to capture storm water in both groundwater basins and surface water reservoirs			management agencies and other agencies to share costs) E. Create guidance on how to plan/develop projects based on local conditions and cost per yield	
2. Lack of guidance to quantify all water and non-water benefits in a multiple-benefit project	No guidance for the identification of multiple benefits for projects	1. Lack of cost savings and implementation of multiple benefit projects 2. Lack of ability to pursue additional funding sources specific to the multiple benefits identified	1. Triple bottom line analysis performed to help identify multiple benefits 2. Multiple-benefit analysis conducted early in the project	A. Guidance on how to perform a multiple-benefit analysis to pull funding from the maximum number of sources B. Stakeholders must acknowledge that	A. Potential to reframe STORMS Phase II project: Develop and Establish a Monetary Value of Stormwater B. Ongoing EPA Project may relate to barrier

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
to solicit additional funds			3. Scale ($) required to support triple bottom line	project partners may have contrasting/diverse motivations for project investments	
3. Roadway infrastructure can be challenging to integrate with stormwater systems due to limitations on funding	Transportation funding sources may not allow funds to be used for stormwater project elements	1. Loss of opportunities for more cost-effective location of water infrastructure 2. New roadways are built without integrated water systems and existing natural ecosystem function is lost	1. Integrated transportation and water systems 2. Transportation funding sources that allow water infrastructure improvements 3. Recognizing transportation corridors (road and rail) as potential stormwater capture and/or distribution locations	Education and outreach to transportation officials and legislators to incorporate water infrastructure and water funding sources into transportation funding	FHWA, NMSA, AASHTO, TRB, NACTO
Education/Guidance					
4. Lack of technical and policy guidance regarding the range of options for centralized	1. Water demand 2. Cost of water 3. Space availability for	1. One-off centralized project designs increase costs and may miss opportunities for efficiency in design	1. Water district experience with centralized capture and use systems (i.e., spreading grounds and infiltration basins)	A. Technical guidance regarding centralized capture and use systems and a tool that calculates the present worth of water	A. APWA, ASCE, EPA, WEF, WERF, AIA B. Related STORMS Project 1d: Develop and Establish a

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
capture and use systems	centralized systems 4. Lack of awareness of available technology		2. Municipal experience of centralized BMPs 3. Los Angeles MS4 permit considers onsite retention (no discharge) of a design storm to meet the alternative compliance standard for receiving water limitations 4. Diffusion of ideas from organizations with experience regarding capture and use and centralized BMPs to those without via a central online location such as the CASQA LID Portal	from various sources across a timescale that includes both excess and drought periods producing a value that would be used to determine the contribution to stormwater funding portfolios and whether the amount is worth pursuing B. Establish a regulatory incentive as a statewide RAA principle that simplifies or eliminates water quality modeling and monitoring efforts for projects that fully retain up to the water quality design storm sized for that watershed	Monetary Value of Stormwater C. Water Boards developing the principles for RAA is ongoing via Project 3a: Develop Guidance for Alternative Compliance Approaches for Municipal Storm Water Permits Receiving Water Limitations and Project 3b: Develop Watershed-Based Compliance and Management Guidelines and Tools; Also related to STORMS Projects to Develop Watershed Based Compliance Management and Tools
5. Lack of public education and outreach to enhance acceptance of capture and use	1. Stormwater management (i.e., green infrastructure) looks different	1. Fewer capture and use systems being built due to public pressure to not use public funds for systems that are not understood	1. Outreach efforts that educate the public about stormwater capture and use and its multiple benefits	A. Statewide education campaign about stormwater capture and use B. Guidance on outreach to	A. Protect Every Drop partners B. EPA, APWA, LGC or other national agency C. NMSA, EPA, WEF

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
at different scales (i.e., regional, neighborhood, parcel)	2. Perception of consolidating contaminants 3. Lack of public education and outreach about different scales of capture and use systems 4. Lack of understanding at the public and decision maker level	2. Less than optimal solutions due to lack of understanding of project benefits and impacts	2. Numerous small-scale, neighborhood-accessible outreach meetings 3. Field outreach events in neighborhoods where projects will be built 4. Outreach to public officials	communicate triple bottom line and approach and increase community ownership of water project decisions C. National programs to educate decision makers	

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
6. Roadway infrastructure can be challenging to integrate with stormwater systems due to well established planning and design standards	1. Limited roadway rights-of-way 2. Lack of guidance on integration of stormwater capture and use and green infrastructure into existing or new roadways	1. Loss of opportunities for more cost-effective locations of water infrastructure 2. New roadways are built without integrated water systems and existing natural ecosystem function is lost	1. Integrated transportation and water systems 2. Recognizing transportation corridors (road and rail) as potential stormwater capture and/or distribution locations 3. Some guidance available on green streets and NCHRP for volume capture in highway environments (NCHRP Report No. 802; Raje et al. 2013)	Education and outreach to integrate water capture infrastructure into transportation projects	FHWA, NMSA, NACTO, AASHTO, TRB, APA

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
7. All non-potable water demands are met	Existing recycled water infrastructure already in place meets non-potable demand	Reduced implementation of capture and use	Focus on restoration of natural ecosystem function to restore or enhance desired ecosystems	Education and outreach	Joint promotion by Water Boards, CASQA, CWH, LID Center, LIDI CWP, Water Foundation, and similar advocates
8.1 Lack of awareness of opportunities to capture smaller flows from flood control detention basins **8.2 Lack of knowledge of downstream water rights**	1. Flood control capacity 2. Maintenance 3. Cost of retrofits 4. Timing of use of water 5. Flood control basins are often not managed by MS4 programs 6. Agencies are unfamiliar with existing infrastructure across their respective counties (NRA and DWR 2013) 7. Existing rights map is	1. Dry weather flows or smaller storms are not effectively used 2. Distributed systems are constructed at higher costs relative to retrofitting a flood control basin 3. High cost to assess water rights	1. Hydrologic evaluation of basins 2. Geotechnical evaluations 3. Demand and timing analysis 4. Groundwater recharge need 5. Larger projects have economies of scale to support the cost of water diversion application	A. Guidance for evaluation and design of retrofit of flood control basins for capture and use (IRWD 2012) B. Better water rights data	DWR, NAFSMA, NMSA, State Water Board

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
	difficult to navigate				
9.Timing for the use of captured stormwater	1. Irrigation water may not be needed for months after storm event 2. Time of demand 3. Vector control can become an issue for extended storage periods	Low oxygen in water stored for long periods of time requires additional treatment at more cost	1. Alternative demand (besides irrigation) 2. Infiltration to aquifer 3. Long-term storage	A. Guidance for storage of capture and use water for irrigation and identification of innovative technologies to expand storage times B. Clarify regulatory constraints	ARCSA, AWWA, National Blue Ribbon Commission for Onsite Non-Potable Water Systems
10. Lack of triple bottom line analysis for watershed plans that would identify and rank multiple benefits including water supply for projects	1. Minimal understanding of triple bottom line by watershed plan proponents 2. Guidance for identification of multiple benefits non-existent 3. Guidance on performing triple bottom line for	1. Reduced implementation of multiple-benefit projects 2. Implementation of stormwater and watershed projects that do not consider environmental and social impacts and benefits 3. Lack of public support 4. Reduced implementation of projects that increase	1. Integration of triple bottom line at the beginning of a watershed plan 2. Water districts as part of the stakeholder group for a watershed plan 3. Triple bottom line criteria and value setting steps included in the public and stakeholder outreach process	Statewide requirement and guidance on using triple bottom line analysis for: 1. Watershed planning 2. Stormwater projects and programs 3. Water supply plans 4. IRWMP and SWRP guidance	DWR, APWA or Envision for triple bottom line guidance

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
	watershed planning non-existent	resiliency to climate change			
11. Lack of consideration of stormwater as a supply	Lack of connection between types of water infrastructure GIS	Lost opportunities to implement projects with water supply function	Regional policies that are supportive of stormwater as a supply (LADWP 2006)	Expand the DWR Water Management Planning tool to incorporate stormwater infrastructure and analyze stormwater as a supply source.	DWR
Institutional/Policy: Regulatory Legal					
12.1. Unknown design criteria for supporting ecosystems by protection or restoration of natural hydrologic function **12.2. Other potential environmental impacts**	1. MS4 permitting treatment sizing may not be appropriate for capture and use 2. MS4 permits do not specify design standards for capture and use vs. treat and release (the same design storms are often assumed for both)	1. Oversized systems that are expensive to implement leads to fewer systems implemented and a smaller fraction of watershed restoration 2. Under-designed systems (too small) result in incomplete restoration of natural ecosystem function 3. Implementing systems that cause an altered water balance and results in habitat or other ecosystem impacts exacerbates a groundwater quality issues	1&2. Permit language that requires retention unless technically infeasible (Caltrans), but limiting the retention target to the water quality design storm reduces chance of oversizing 2. Phase II Permit recognizes the benefits of developing design criteria based on local watershed conditions and processes (e.g., Central Coast Phase II sizing approach) 3&4. Site-specific analysis and careful design	A. Modeling the desired water balance in MS4 areas throughout the state as a regulatory or voluntary target for capture and use; consider desired ecosystem objectives (see STORMS Project 1 C) B. Quantify (or develop methods to quantify) evapotranspiration, shallow infiltration, and deep infiltration relative to annual average precipitation C. Investigate the circumstances where	A. Water Boards (Related to STORMS Phase II Project 3f: Develop Guidance for Post-Construction Requirements to Improve Watershed Health) B. State Water Board C. CDFW

Barriers	Drivers (Causes)	Consequences (Effects)	Factors Affecting Success in Case Studies	Potential Projects for Statewide Solutions	Potential Lead Agency or Advocate of Solution
		4. Projects that have unanticipated environmental impacts will decrease public support for future projects and contribute to unfounded concerns for future projects with no likely impacts	3&4. Coordination with resource agencies and experts 3&4. Integration of environmentally beneficial design features	stream dewatering might be a constraint worthy of site-specific analysis, develop factors to consider that would trigger the need for further analysis, and guidance on scale of project that would need study	
13.1. Inconsistent regulations regarding restricting infiltration based on land use (e.g., industrial land uses) for protection of groundwater **13.2. Inconsistent pretreatment requirements for protection of groundwater** **13.3. Lack of state-endorsed drywell**	1. Regional Board autonomy 2. County autonomy 3. Lack of detailed understanding of surface water effects on groundwater motivate many counties to take a conservative (and restrictive) approach, while others may not be adequately protective. Implementatio	1. Potential contamination of groundwater by infiltration of pollutants (e.g., selenium) 2. Reduced implementation of infiltration when appropriate results in lost opportunities to recharge groundwater, restore natural ecosystem functions, and reduce surface water pollutant loads 3. Potential groundwater contamination or exacerbation of existing groundwater conditions (i.e., selenium issues in	1, 2 & 3. Regulations based on understanding of pollutant sources, quantities, and fate and transport to extractable aquifers 1, 2 & 3. Understanding of natural hydrologic and hydrogeomorphic processes to support ecosystems 1, 2 & 3. Site-specific information regarding groundwater and surface water interaction, local contamination plumes, and stormwater quality	A. Develop statewide regulation regarding restriction of infiltration based on land uses or pretreatment performance standards; determine appropriate application of MCL and basin plan objectives, addressing pretreatment vs. attenuation within the vadose zone; consider recent research results on passive treatment approaches to protect groundwater (Beganskas and Fisher 2017); and address WQO 68-16	A. Ongoing Water Boards project B. Water Boards C. CASQA D. DWR

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
standards and pretreatment performance standards **13.4. Lack of clarity regarding anti-degradation policy as applied to groundwater**	n of the Sustainable Groundwater Management Act (SGMA) may lead to an increased understanding of surface water effects on groundwater or may cause unnecessary caution or analysis 4. WQO 68-16	Newport Bay Watershed)		B. Training and education of Regional Water Board staff C. Training and education of county regulators D. State-endorsed drywell design standards	
14. Different Department of Public Health (DPH) requirements and guidance for use and treatment of captured stormwater for direct use	1. Public health threats from direct use of stormwater 2. Autonomy of local public health agencies	1. New learning curve for implementing capture and use systems in different jurisdictions 2. Longer timeframe for implementing capture and use systems	1. The flexibility to use purple pipe for distribution of captured and treated stormwater 2. Availability of DPH staff for pre-project meetings with proponents to coordinate and understand regulations	A. Develop stormwater treatment and piping distribution guidance (WEF 2014) B. Adopt treatment requirements that do not require Title 22 for all captured stormwater that would exclusively use existing, unused purple pipe (no comingling with recycled water)	AWWA or other professional association (except DDW because they don't have explicit regulations on stormwater treatment for non-potable uses); Water Boards (low priority due to limited applicability and potentially short-term issue once POTWs are

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
					upgraded to use purple pipe); National Blue Ribbon Commission for Onsite Non-potable Water Systems may be addressing this issue at a national level
15. Constraining, competing, or inconsistent local regulations among jurisdictions	Different levels of government are not coordinated regarding requirements	1. Impedes training design professionals and MS4 plan reviews 2. New learning curve for implementing capture and use systems in different jurisdictions 3. Longer timeframe for implementing capture and use systems	Coordinated regulations based on common science-based approach and adopted at different levels of government	Develop model policies, regulations, or amendments that local jurisdictions will be able to replicate and integrate into their regulatory structure; various project timelines to address different policy barriers may make a single project difficult to implement	No specific lead identified, but all projects with regulatory implications should include a review of local regulations to identify conflicts and recommend improvements
16. Multiple-benefit projects that provide a water supply benefit do not receive preference over projects that do not offer	1. Multiple-benefit projects are not valued significantly more than other projects 2. Water supply benefits are not significantly valued more	1. Lost opportunities to achieve optimal multiple social and environmental benefits via projects 2. Increase social costs of separate projects to achieve singular benefits	Some funding sources have criteria for funding that significantly values multiple-benefits projects higher than other projects	A. Establishing funding criteria for multiple-benefit projects B. Perform simplified triple bottom line analysis as part of project evaluations	Although issue is acknowledged in STORMS Project and CASQA funding website, more might be done through CASQA, AWWA, APWA, and EPA

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
multiple benefits	than other benefits				
17. Downstream water rights	State Law; prior downstream appropriation; unknown risk	1. Added cost to determine rights 2. Decreased capture	California Rainwater Capture Act of 2012 clarified that use of rainwater collected from rooftops does not require a water right permit from the State Water Board (Wat. Code §§ 10570 et seq)	Change in state law	State Water Board
Institutional/Policy: General					
18. Developers are not required to consider stormwater capture and use options early enough in the entitlement process	1. Stormwater and LID are not an integrated step and municipalities do not require stormwater capture/LID consideration early enough in the entitlement process 2. Lack of LID site planning/site design and stormwater capture and use training/guidan	1. Additional redesign costs or increased costs due to retrofitting after the development is built 2. Fewer opportunities for preservation of natural ecosystem due to development of prime areas for BMPs	1. Long-term land use planning considers stormwater a potential water supply 2. Green infrastructure provides a number of benefits including improved water quality, reduced flood losses and infrastructure costs, and cost savings of combined sewer overflow mitigation 3. Studies tying real estate values to presence/absence of green infrastructure found that total	Guidance for stormwater capture and use planning for developers and municipal planners to be adopted into city and county ordinance governing entitlement (see Johnson and Loux 2010, for insights on California water planning); groundwater and surface water conflicts and information on policy to address water needs in CEQA noted here: http://waterinthewest.	APA, CASQA, Governor's Office of Planning and Research, ULI

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
	ce for developers 3. Developers prefer not to deviate from past development processes		benefits to property owners on average is 2-5% of property value for all properties within a flood plain (Braden 2004) 4. Results of completed LID projects indicate that the higher initial landscape cost of LID are offset by decreased costs associated with infrastructure and site preparation; on average LID projects can be completed at a cost reduction of 25-30% over conventional projects (Hager 2003; CA LID Portal 2017)	stanford.edu/groundwater/conflicts/index.html	
19. Lack of communication and collaboration among agencies (primarily	1. Water districts prefer the cleanest and most reliable sources and	1. Lost opportunities for areas where stormwater capture and use is viable 2. Less groundwater recharge in key	1. Established relationships among agencies 2. Third party intervention (i.e., developer)	Increased incentives (i.e., grant programs or State Revolving Funds or SRF that require water suppliers and stormwater dischargers	Ongoing coordination effort within the State Water Board between DFA and SGMA to ensure GSAs recognize

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
municipalities and water districts) on opportunities for stormwater capture and use projects	groundwater contamination concerns may result in additional analysis requirements for stormwater infiltration projects 2. Lack of understanding of other agency regulatory drivers 3. Lack of successful examples for collaboration 4. Lack of interest due to capture amounts 5. Cost of potable water	locations for water districts 3. Less resiliency in the water management systems to combat the effects of climate change	3. Common regulatory driver (i.e., TMDL) 4. Political support/policy (e.g., LA Mayor's Executive Directive to reduce the City's purchase of imported water by 50% by 2024)	to collaborate); SGMA implementation can foster stormwater recharge partnerships with MS4 runoff	MS4 runoff capture opportunities
20. Lack of triple bottom line analysis for non-water infrastructure that could	Incorporating multiple benefits can be perceived as scope creep and as adding	1. Lost opportunities for cost savings and for integration of capture and use and restoration of natural ecosystem functions	1. Coordination among many different agencies 2. Address increased project risk associated	A. Concept paper identifying non-water infrastructure that has the highest opportunity for integration of stormwater capture	APWA, Envision, APA, Governor’s Office of Planning and Research

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
incorporate capture and use	risk to the project and jeopardizing the primary objective	2. Loss of cost savings as stand-alone capture and use projects will need to be implemented	with adding stormwater	and use and how it could better support water infrastructure and vice versa; Envision and tools from APWA may provide a start B. Perform an in-depth analysis to evaluate the urban form when developing new communities or subdivisions or refurbishing older communities to better integrate stormwater capture and use and LID principles (e.g., permeable surfaces and bioretention) and show how triple bottom line can be done in the context of stormwater capture and use	
21. Lack of triple bottom line analysis of environmental benefits of	Multiple environmental benefits	1. Lack of implementation of multiple-benefit projects 2. Lack of identification of multiple benefits and	Triple bottom line analysis for all project alternatives and/or project elements	Triple bottom line analysis guidance for stormwater projects and programs, including the value to out-of-basin water	California Natural Resources Agency, DWR, etc.

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
stormwater capture and use		other funding sources specific to the multiple benefits 3. Lost opportunities to gain further public support for projects by evaluating the social benefits of projects 4. Lost opportunities to implement truly sustainable projects that are resilient to climate change 5. Inability to compare projects with similar costs that have different levels of environmental and social benefits		sources that will have less demand, reduced environmental impacts, and reduced energy consumption for water delivery	

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
22. Lack of state approval for design and performance of treatment, storage, and distribution technologies for direct use	1. Lack of funding for testing program 2. Administrative burden	1. Lack of confidence and high risk limits innovation 2. Use of systems that do not work 3. Use of systems that are needlessly expensive	Comprehensive testing with 3rd party oversight	State or federal testing program for BMPs and technologies for direct use (irrigation, indoor, etc.); expand WEF's STEPP to address capture and use; track ongoing development around the world including work in Australia (Feldman 2017)	ITRC, ASCE, WEF, WERF, NMSA, ASTM, AWWA, ARCSA; related STORMS Project 5a will develop data standards for green infrastructure and LID BMPs to inform a standard set of monitoring information and meta data so that a more comprehensive analysis is possible

Barriers	*Drivers (Causes)*	*Consequences (Effects)*	*Factors Affecting Success in Case Studies*	*Potential Projects for Statewide Solutions*	*Potential Lead Agency or Advocate of Solution*
23. Lack of financial mechanisms for agencies to combine resources	1. Agencies have individual budgets and budgetary processes 2. Joint power authorities (JPAs) are a solution but are difficult to establish	Loss of opportunities to implement centralized projects due to costs and program authorities	1. Agreements on joint agencies pursuing funding 2. Collaborative planning to integrate and combine funding	Promote GSA JPAs that include MS4s as signatories (see DWR fact sheet for GSA formation)	DWR and DWQ with DFA/SGMA; related STORMS Phase II project: Increase Stakeholder Collaboration to Promote Stormwater as a Resource
Technology					
24. Competing uses for rights-of-way in high density development settings	1. Utilities 2. Limited rights-of-way	Integrated water infrastructure rarely materializes in ultra-urban settings	1. Innovative design for new buildings and roadways 2. Upgrade of utilities and integration of stormwater infrastructure	A. Integration of stormwater capture infrastructure with utilities and other infrastructure B. Triple bottom line and multiple benefit guidance for all infrastructure	APWA, EPA, FHWA, Envision, etc.

4.6 Creating or Increasing Incentives

Incentives provide motivation. In the near term, the next phase of projects addressing capture and use are largely addressing barriers, so outside of funding sources or regulatory relief, these projects may not provide incentives. Current incentives include:

- Total maximum daily load (TMDL) and alternative compliance paths to receiving water limitations
- Water supply resilience
- Sustainable groundwater requirements
- Groundwater salinity intrusion
- Subsidence
- Ecosystem management, especially for endangered and threatened species

These incentives do not apply equally throughout the state. For example, TMDLs and alternative compliance have thus far excluded small, rural municipalities due to fewer TMDL drivers. Also, water supply costs vary so this is an inconsistent motivator for stormwater capture and use. Sustaining groundwater levels will provide some incentives for GSAs to partially fund urban runoff deep infiltration projects at price points that relate to local water market pricing.

5 Findings and Recommendations

Findings represent the key messages for the stormwater community based on input from the project team, TAC, and PAG. Recommendations contain a summary of next steps on the primary projects identified in Table 2.

5.1 Findings: Constraints and Barriers

These findings are meant to focus on successfully implementing capture and use projects, despite the barriers identified in the study. By presenting barriers in the context of successful projects, these findings are meant to summarize ways of supporting project proponents in their implementation of capture and use. The following twelve findings have been grouped into five categories. They range from supporting new efforts and policies to eliminating barriers and developing messaging for public outreach emphasizing the benefits of capture and use. The first group, Motivating Change, might be the most critical in promoting capture and use. As seen in case studies and comments from municipalities, most barriers are overcome when people have the will to change how stormwater is managed. The remaining groups are Viable Urban Water Supply, Better Information Needed, Identifying Tradeoffs and Consequences, and Hybrid Strategies.

Motivating Change

Finding 1: Capture and use projects or BMPs that increase on-site runoff retention also reduce the effects and associated liability of discharging to local watersheds. A project or BMP that mimics the pre-urban hydrologic condition (e.g., surface runoff volumes/rates, infiltration, evapotranspiration) also preserves (new construction) or restores (retrofit construction) ecosystem processes, thereby setting a context for sustainable water resource management by managing water volumes appropriately to protect historic ecologic end use. Additionally, the cost of achieving water quality standards in surface waters is reduced when natural watershed processes are present. Further studies are required to quantify the water quality benefits and to properly credit capture and use toward water quality goals such as TMDLs.

Finding 2: Public engagement is key to increasing BMP integration into other public and environmental objectives, and it will increase the likelihood of robust, multiple-benefit, and cost-effective projects. Consistent and effective messaging is a critical component to engaging the public and increasing community buy in. Specialized expertise and broad coordination (CASQA 2017a) will also help formulate and convey messaging efforts.

Viable Urban Supply

Finding 3: Urban runoff can provide a sizeable water supply. In some parts of the state, urban stormwater runoff currently constitutes 10% or more of urban supplies. Utilizing urban runoff as a supply augments and diversifies water portfolios. Diversified regional water portfolios will relieve pressure on foundational supplies and make communities more resilient against drought, flood, population growth, and climate change (CNRA 2016).

Finding 4: Technological limitations were not reported in case studies. Instead, reported barriers relate to policy, finance, institutional structure, and awareness. Awareness of technological capabilities can overcome some perceived barriers. For example, space limitations and lack of permeability in near-surface soils are perceived barriers that can potentially be addressed by increased awareness of drywell technologies.

Finding 5: Given California's varying climate, it is likely infeasible to meet all urban demands using stormwater capture alone. The scale of capture and use required to meet typical urban needs would necessitate volume storage that is many times greater than current stormwater design storms. Additionally, since this volume typically falls over a span of several storms throughout the year in most parts of the state, peak volume storage would be extensive. Due to these large storage requirements, urban areas with underlying aquifers are ideally situated to capture and store water, as aquifers provide a cost-effective storage solution and clearer path to overcoming existing storage barriers for capture and use projects. Where aquifer storage is not available, methods such as conservation and surface water capture should be emphasized. The location of capture facilities in relation to the location of desired end uses is another key to controlling distribution cost.

Better Information Needed

Finding 6: In most parts of the state, using urban runoff as a water supply is more expensive than utilizing existing sources. Distributed stormwater capture, which is easier to implement in dense urban areas, is more expensive, while larger centralized stormwater capture requires substantial tracts of land that can be difficult to site in densely urbanized areas. When comparing stormwater capture to existing sources it is important to realize that current water rates often do not accurately reflect full water supply costs. Existing water supply infrastructure was built and paid for in part decades ago.

Improved rate-setting procedures in water districts could allow for better comparisons of existing and new infrastructure cost estimates. While there may be limitations associated with Proposition 218, sunken treatment costs should be considered as well as the incentive provided by clean water act regulation. Water districts can contribute to proper valuation by using rate setting techniques that consider factors such as increasing environmental costs associated with different water sources and cost increases associated with likely climate change scenarios that can cause water scarcity. Water districts typically set standards based on a 5-year future projection, which fundamentally limits their ability to make investments in alternative water sources based on longer term changes (City of Vallejo 2016).

Finding 7: Standardized procedures or decision support tools do not currently exist for stormwater capture and use planning. Several major stormwater planning applications now include modules to support LID and BMP implementation, but cost and performance data is dispersed and few studies have effectively considered the potential for stormwater capture to comprise a significant source of urban water supply. Capture and use approaches are typically more expensive than upgrading existing grey infrastructure when comparing new vs. marginal cost increases, and when failing to include benefits and costs for environmental and social aspects of system management.

Improving valuation—both economic and non-economic—of capture and use can increase community and political support, which helps overcome financial and institutional barriers. Increased capture and use could be realized by recognizing the benefits of capture and use on water quality, air quality, education, and health-related benefits. Small-scale options for stormwater management also offer municipalities an opportunity to implement capture and use projects that support local economic activity, rather than relying on specialized labor and materials from outside the local area (WEF 2014). Proper valuation of multiple-benefit projects will also make capture and use projects more attractive for various funding sources (e.g., transportation). Decision support tools can assist in optimizing new system designs with green and grey infrastructure that better promote sustainable and holistic water management, exemplified by *OneWater* approaches being pursued in some areas of the state.

Finding 8: Stormwater infrastructure can support multiple objectives to provide the greatest benefits, but these must be considered early in the design process. For example, centralized strategies can more effectively achieve multiple benefits when agencies charged with managing different types of natural resources collaborate to meet resource objectives (e.g., water supply, flood control, habitat, air quality, receiving water protection). Decentralized strategies tend to be implemented within land uses that are primarily dedicated to other infrastructure (e.g., transportation). Choosing approaches that support a diversity of infrastructure will be critical in marshalling funding designated for that infrastructure.

Finding 9: There are thousands of stormwater control measures (e.g., flood control facilities and stormwater detention basins) in California, so retrofit or modification of existing regional facilities is a promising strategy to substantially increase capture and use. Better regulations clarifying uncertainty regarding existing water rights diversions and capture and use may encourage small-scale retrofits where the cost of investigating rights is high compared to the benefit derived from the project. Central repositories for regional data on BMP, LID, and capture and use performance and costs would support improved planning processes. In particular, regionally centralizing databases for runoff and flood infrastructure, which are currently housed in more than 1,000 different flood control agencies statewide, could be brought together in regional databases in support of opening access to information that allows for a more accurate assessments of benefits (DWR 2013).

Identifying Tradeoffs and Consequences

Finding 10: Developing appropriate targets for capture and use requires considering the complex tradeoffs between benefits of capture and use as well as potential unintended consequences. For example, existing ecosystems that are dependent on current urban runoff flow regimes may support endangered species. Increased capture and use management strategies could reduce the flows that support these species. A framework for valuing the support of post-development ecosystems is needed to further evaluate the potential effects that capture and use projects may have on species that rely on elevated urban runoff flow regimes. Negative groundwater quality impacts is another example of unintended consequences.

Hybrid Strategies

Finding 11: Future urban water management will require a mix of green and grey infrastructure. Costs, technologies, and social views are driving this trend toward hybrid systems. According to case studies, technology has not been reported as a barrier for capture and use projects; financial and policy barriers far exceed technical limitations. With respect to hybrid systems, this means designing green and grey infrastructure that use distributed infrastructure to capture and attenuate runoff throughout the landscape, coupled with key larger municipal infrastructure that assures performance. But, best practices for design and management are unclear and risks are still significant. For instance, decentralized capture and use strategies on private land may not be well maintained over time. Alternatively, investing in large infrastructure is expensive and may not directly achieve receiving water requirements or estimates of groundwater recharge, stifling additional investments. (Sedlak 2013; NAS 2016; Porse 2013).

Watershed scale decisions may fit well within IRWM planning and municipal general planning efforts that could require consideration of local stormwater as a supply source. The knowledge, guidance, and funding to conduct triple bottom line cost-benefit assessments for watershed ecosystems is needed to identify the optimum mix of green and grey infrastructure. MS4 permits and municipal code may need adjustments to allow for that mix. At a smaller scale for a particular development, decisions often rest with the developer.

Finding 12: Applying fit for purpose standards to the different uses of urban runoff may reduce unnecessary treatment costs. For example, risk-based treatment standards applied to harvested water for protection of public health based on likely exposure may result in decreased costs of direct use systems (SFPUC 2013).

5.2 Promising Actions

Some of the potential projects identified in Section 4.5 appear ready for further scoping and implementation. These projects and, where appropriate, actions identified in the CASQA Vision (2015) that may align with these projects are identified. The state actions also list the agencies best suited to lead the projects. Additional projects and organizations are listed in Section 2.3, however these local and state actions are recommended for immediate implementation.

Local Actions

1. Collect data necessary for asset management and justification for stormwater fees and develop costs for agreed-upon customer and environmental water services while minimizing life cycle costs (CASQA Actions 2.7 and 2.8)
2. Update municipal general plans to require consideration of stormwater as a water supply source (CASQA Action 1.1)
3. Align or leverage water services (e.g., water supply, flooding) with capture and use to the benefit of both (e.g., Hansen Spreading Grounds)
4. Use alternative analysis tools to engage stakeholders and develop support for water infrastructure that delivers social, economic, and environmental benefits (CASQA Action 2.5)
5. Capture and use project advocates (e.g., water districts and MS4 programs) coordinate with local and state transportation authorities to look for opportunities for shared projects and benefits such as the Elmer Avenue Stormwater Capture Project (CASQA Action 3.1)

State Actions

1. Explore options for funding stormwater capture and use (refer to Projects 4A and 4B as well as CASQA Action 2.7; State Water Board)
2. Improve consideration of urban runoff in IRWMPs (CASQA Action 1.1; State Water Board, DWR)
3. Resolve the policy questions regarding use of promising technologies and approaches
    a. Resolve regulatory and policy issues related to the use of drywells for stormwater management (State Water Board)
    b. Update IRWM guidelines and the online Water Management Planning Tool (http://wdl.water.ca.gov/irwm/) to consider local urban runoff as a potential source (DWR)
    c. Improve land use codes governing building footprints to adopt performance standards for new development and redevelopment to support decentralized capture and use technologies, such as LID for municipalities (Office of Research and Planning)
    d. Establish a framework to assess local ecological impacts, positive and negative, to capture and use diversions (DFW, State Water Board).
4. Expand/improve regulatory performance measurements to reflect capture and use objectives (State Water Board)
    a. Develop/align post-construction stormwater control requirements for capture and use objectives based on factors such as watershed processes, public use needs, and ecologic value of current flow regimes
5. Identify the most effective and feasible capture and use strategies
    a. The number, location, and volume of stormwater/flood control basins are a prime opportunity for significant benefit, so evaluate the regional and statewide

opportunity to retrofit conventional detention basins to enhance capture and use (DWR or provide funding to local flood and stormwater agencies).

b. Establish design guidelines for public projects reflective of capture and use objectives (Water Board)

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