STORMWATER CAPTURE TO AUGMENT WATER SUPPLIES IN THE SAN FRANCISCO BAY AREA

Challenges, Opportunities and Next Steps

BAY AREA ONE WATER NETWORK | JULY 2019

ABOUT THIS REPORT

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This report is the first in a series of documents developed by the Bay Area One Water Network to assess options for advancing water system sustainability, resilience and security in the San Francisco Bay Area (Bay Area). By sharing lessons learned, showcasing successes and identifying best practices, we aim to provide decision makers with tools to meet the Bay Area's future water needs.

An integrated approach to water resources management that includes stormwater capture and use will allow municipalities, private developers and utilities to meet future water demands in an economically feasible way. Stormwater capture also offers multiple benefits such as community improvements, flood control and pollution reduction.

This report presents the findings from a two-day workshop focused on stormwater capture for augmenting urban water supplies, held in San Francisco, California on July 25-26, 2019. At the meeting, stormwater capture and use were considered as one potential water management opportunity for communities throughout the region. This report describes the history and current state of stormwater capture for water supply in the Bay Area; describes case studies of innovative stormwater management; delineates the regional drivers for the practice; and identifies a range of opportunities for stormwater capture and use. Finally, the report specifies next steps for advancing stormwater capture in the Bay Area.

The Berkeley Water Center and the Meridian Institute prepared this report with support from the sponsors of the Bay Area One Water Network, the National Science Foundation's Engineering Research Center for Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt), and the US Environmental Protection Agency. It reflects synthesis and interpretation of presentations and discussions from the July 2019 workshop, but is not intended to be a comprehensive assessment of the opportunities for stormwater capture for water supply in the Bay Area. Rather, the intent is to spur further consideration, discussion, and action.

See Appendix A for a list of workshop participants.

For more information about the Bay Area One Water Network, please visit www.bayareawater.org or contact Sasha Harris-Lovett (sharrislovett@berkeley.edu).

Suggested Citation: Harris-Lovett, Sasha, Kara Baker, Molly Mayo, David Sedlak, and Richard Luthy. "Stormwater Capture to Augment Water Supplies in the San Francisco Bay Area: Challenges, Opportunities, and Next Steps." Bay Area One Water Network, July 2019.

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Report Design: Cassidy Gasteiger, Meridian Institute

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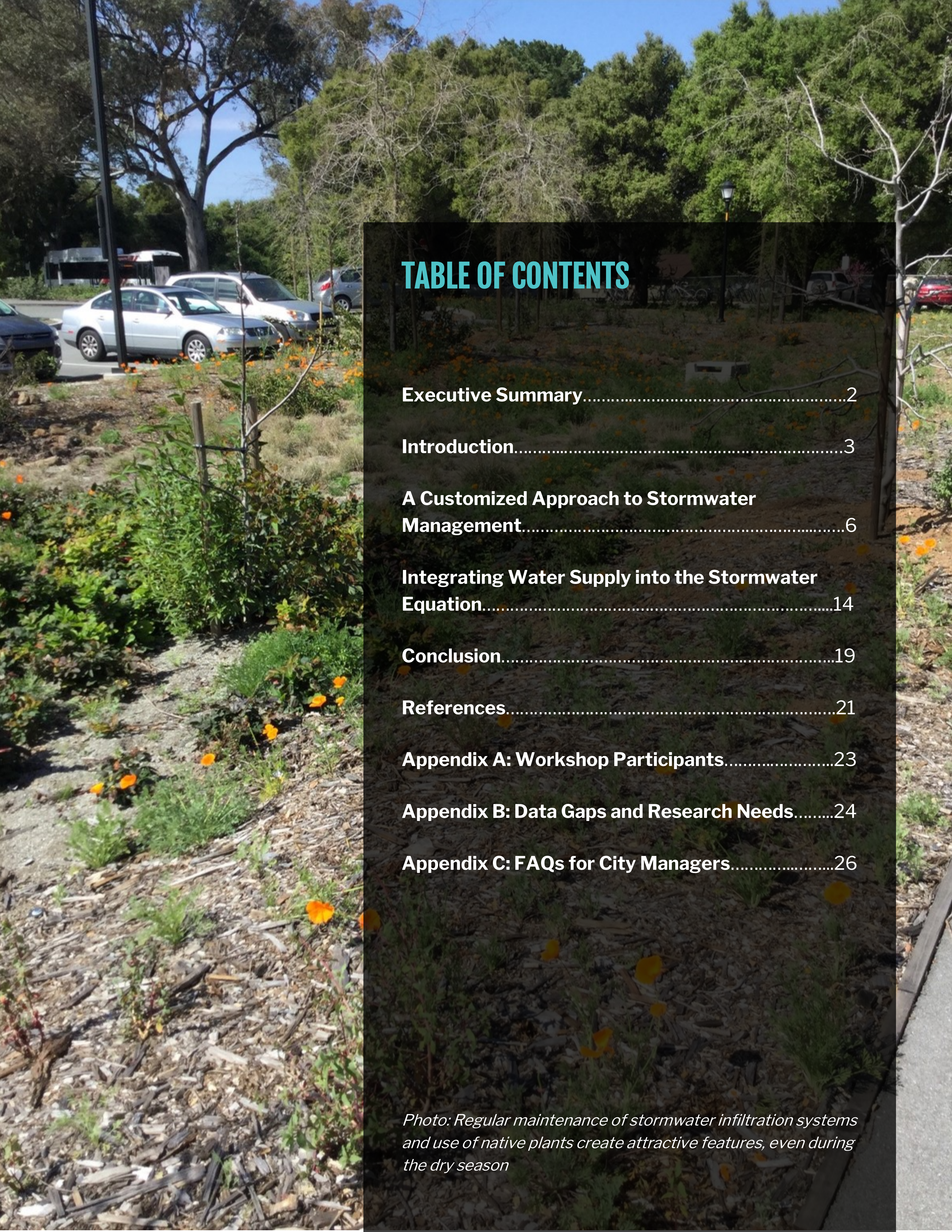

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Photo: Regular maintenance of stormwater infiltration systems and use of native plants create attractive features, even during the dry season

EXECUTIVE SUMMARY

This report provides a summary and synthesis of the Bay Area One Water Network's workshop on stormwater capture to augment water supplies in the San Francisco Bay Area, held July 25-26, 2019 in San Francisco. The workshop brought together professionals in organizations responsible for stormwater management, water supply and wastewater treatment along with professionals from regulatory agencies, non-profits, and academia to discuss the potential of stormwater capture as a water supply option in the Bay Area.

With the prospect of urban water scarcity in California's future, Bay Area water managers are seeking solutions to enhance the security of their water supplies. Stormwater is a locally available water source that could help diversify the region's water supply portfolio. Stormwater capture in the Bay Area is challenging because much of the region's geology is not conducive to infiltration of stormwater into groundwater aquifers. Nonetheless, stormwater capture is attractive because it can be cost-competitive with other new water supply options, it can reduce adverse effects of stormwater on local waterways and it can provide additional benefits like urban greening, wildlife habitat and flood prevention. The State of California is actively promoting stormwater capture, and it may be possible to leverage both existing infrastructure (i.e., for flood control) and existing funding opportunities to support stormwater capture projects.

Workshop participants considered four opportunities for stormwater capture in the Bay Area:

1. Large-scale stormwater capture and diversion to a place where it could be infiltrated to groundwater or stored in a reservoir;
2. Neighborhood-scale stormwater capture (i.e., at parks and ballfields) as part of green infrastructure projects;
3. Diversion of stormwater to wastewater treatment plants for reuse; and,
4. Household-scale cisterns and rainwater capture projects.

Each of these types of stormwater capture may play a role in the region's future water supply portfolio. Regional coordination can ensure that stormwater capture projects are equitably distributed, cost-effective, and maximize multiple benefits.

As workshop participants discussed these opportunities, it became evident that strides in several key areas could help advance stormwater capture in the Bay Area.

Key Steps to Advance Stormwater Capture

1. Increased research to fill region-specific data gaps (see Appendix B for a list of research needs)
2. Development of metrics for stormwater capture co-benefits to inform decision-making
3. Assessment of ways existing infrastructure could be leveraged to enhance stormwater capture
4. Continued integration of stormwater capture into existing local and regional planning documents
5. Analysis of funding options for stormwater capture in the Bay Area
6. Expanded capacity of existing groups working on planning and implementing integrated water management to incorporate stormwater capture, and expanded opportunities for communication between stormwater managers and water suppliers

INTRODUCTION

San Jose Creek (Sunburned Surveyor)

Pier 14 in San Francisco during peak high tide conditions (Paul Chinn, The Chronicle)

For much of the twentieth century, stormwater management was focused on flood control. In the Bay Area, this resulted in channeling streams to deliver runoff as quickly as possible to the bay or ocean. Except for San Francisco (which operates a combined sewer system), stormwater in the Bay Area is conveyed in municipal separate stormwater systems (MS4s) that are regulated through discharge permits.

Failure to rapidly move stormwater out of cities can result in flooding and disease vector problems, while the extensive coverage of paved surfaces in urban areas and the Bay Area's steep hills makes it likely that stormwater will cause hydro-modification and habitat destruction. From a water quality perspective, stormwater has polluted the San Francisco Bay with toxic contaminants like mercury, copper and pesticides, and more recently, it has been identified as a major source of micro-plastic particles to the Bay. [1] Nationwide, stormwater management often is synonymous with costly projects aimed at decreasing environmental impacts.

Despite its historic reputation as a nuisance, stormwater is increasingly being seen as a potential water supply, particularly in water-stressed regions.[2] With the prospect of more severe droughts in California's future, and other stresses on urban water, many California cities are now looking at stormwater as a possible locally-available water source to augment urban water supplies. Major programs for employing stormwater as a source of water supply are under consideration in the Bay Area, and many of the region's water professionals acknowledge the potential of stormwater to help diversify the region's water portfolio going forward. Prior to making major investments in such programs, local decision-makers need a better understanding of the challenges and opportunities associated with this underexploited water resource.

Stormwater capture as a source of water supply is also attractive because it has the potential to address other needs of the Bay Area. Systems that capture stormwater can also reduce pollutant loads into San Francisco Bay and other surface waters, and provide aesthetically pleasing green spaces that serve as wildlife habitat, afford recreational opportunities, and reduce the impacts of flooding.

This report considers four opportunities for stormwater capture in the Bay Area: large-scale stormwater capture and diversion to a place where it could be infiltrated to groundwater or stored in a reservoir, neighborhood-scale stormwater capture (i.e., parks and ballfields) and green streets, diversion of stormwater to wastewater treatment plants for reuse, and household-scale cisterns and rainwater capture projects.

[1] McKee et al., "Sources, Pathways and Loadings"; Sutton et al., "Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region."

[2] Luthy, Sharvelle, and Dillon, "Urban Stormwater to Enhance Water Supply."

Collaborating for Integrated Solutions

To assess the opportunities and challenges for stormwater capture as a source of water supply, the Bay Area One Water Network held a workshop for a group of thought-leaders and knowledgeable experts from the region's water and wastewater utilities, stormwater management agencies, city governments, advocacy groups, non-governmental organizations, and regulatory agencies (see attendee list in Appendix A). The goals of the workshop were to identify opportunities for advancing projects that would help decision-makers determine the role that stormwater capture can play in the Bay Area's future water portfolio, as well as synergize existing regional efforts. The workshop was also intended to strengthen relationships among the participants and to demonstrate the potential of various types of stormwater management systems in the region.

Designing a "one water" system

This workshop was part of an overall Bay Area One Water Network effort to advance the planning for water system sustainability, resilience and security in the Bay Area. Expanding local water supplies through stormwater capture can be part of a diverse portfolio of options, which could also include conservation, water reuse, desalination, and imported water.

WHY DOES THE BAY AREA NEED A 'ONE WATER' PERSPECTIVE?

Resilient water systems in the Bay Area must increasingly be designed to withstand extremes. The region counted 7.15 million inhabitants in 2010, and expects to accommodate 9.3 million people in 2040.[3] Currently, the majority of water used in the region is imported from the Sierra Nevada. In future years, the region can expect more intense storms, less snowpack in the Sierra, drier and longer droughts, and hotter cities, all of which will affect existing water supplies and demands.[4]

In the next two decades, modernization of the region's water supply to make it more resilient to climate change is imperative. There are multiple options available to the Bay Area including conservation, water reuse, desalination and stormwater capture. Each has different attributes in terms of cost, reliability, availability of funding and public support. The purpose of Bay Area One Water Network workshops is to advance the discussion beyond high-level descriptions and highlight information needed to inform decisions, recognizing that the ultimate solution will likely involve a mixture of approaches, which are implemented after years of demonstration projects and assessments.

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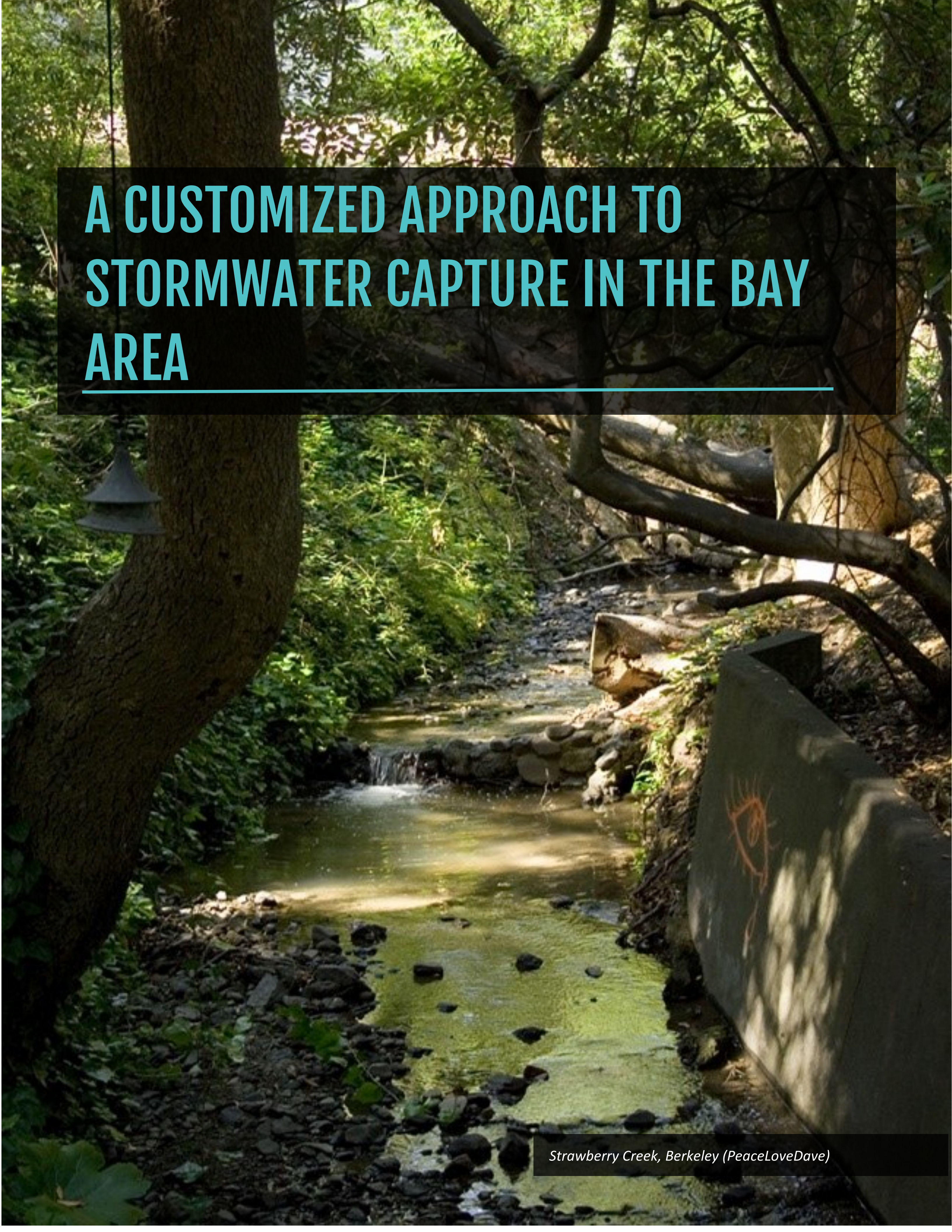
[3] Association of Bay Area Governments and Metropolitan Transportation Commission, "Plan Bay Area 2040."

[4] Ackerly et al., "California's Fourth Climate Change Assessment: San Francisco Bay Area Summary Report"; Dahl et al., "Killer Heat in the United States: Climate Choices and the Future of Dangerously Hot Days."

A CUSTOMIZED APPROACH TO STORMWATER CAPTURE IN THE BAY AREA



Strawberry Creek, Berkeley (PeaceLoveDave)

The Opportunity

The Bay Area encompasses nine counties and over 200 cities. There has been rapid growth in the urban built environment in the past 70 years, resulting in ever-increasing impervious surfaces over which stormwater flows. Estimates of the volume of urban runoff offer some picture of the potential for stormwater to contribute to water supply. Of the 2,800 square kilometers of urbanized land in the Bay Area in the year 2000, approximately 56% of it was impervious surfaces, according to a 2007 U.S. Forest Service report.[5] Assuming the region averages 61 cm (24 inches) of rain per year (a conservative estimate, based on San Francisco rainfall averages – rainfall varies dramatically on a local scale), about 775,000 acre-feet (960 million cubic meters) of rainwater falls per year on impervious surfaces in the Bay Area. Even if only a fraction of that were captured, it would still represent a significant contribution to the region's water supply.

The environmental non-profits NRDC and the Pacific Institute estimated between 365,000 and 440,00 acre-feet/year (450 million and 543 million cubic meters, respectively) of runoff capture potential in urban Southern California and the Bay Area in locations overlying groundwater basins suitable for infiltration.[6] These are optimistic assessments that do not consider site constraints or other logistical issues. The Bay Area Stormwater Management Agencies Association (BASMAA) concludes that much of the Bay Area has geology/topology that would make large scale stormwater infiltration for water supply challenging, particularly because the areas with good infiltration may not be over a drinking water aquifer.[7]

Rory M. Shaw Wetlands Park under construction in Lost Angeles will capture, treat, and recharge urban stormwater (LA Department of Public Works)

The Bay Area's water challenge

California's changing climate, growing population, and expanding environmental awareness mean that the region's current imported water supplies from the Tuolumne and Mokelumne Rivers and Sacramento-San Joaquin River Delta will likely not be adequate in the future.

The Bay Area is not alone in considering the potential of stormwater to augment water supplies. Fresno and Monterey both have begun capturing and using stormwater, and Los Angeles has begun building green infrastructure to capture and use stormwater. For example, the Rory M. Shaw Wetlands Park in Burbank will convert a 19-hectare parcel of land into a detention pond, wetland and park that will capture, purify and infiltrate stormwater into the aquifer. The City of Los Angeles, which has more favorable geology for stormwater infiltration than the Bay Area, is looking to capture 68,000 – 114,000 acre-feet (84 million – 141 million cubic meters) of stormwater beyond today's 64,000 acre-feet (79 million cubic meters) of incidental and active stormwater recharge. With an estimated water demand of about 700,000 acre-feet/year (863 million cubic meters/year) in twenty years, new stormwater capture could account for 15% of that supply.[8]

[5] Simpson, James and McPherson, E. Gregory, "San Francisco Bay Area State of the Urban Forest Final Report."

[6] NRDC, "Stormwater Capture Potential in Urban and Suburban California."

[7] Geosyntec Consultants, "Harvest and Use, Infiltration and Evapotranspiration Feasibility/Infeasibility Criteria Report."

[8] Los Angeles Department of Water and Power, "Stormwater Capture Master Plan," August 2015.

An Underutilized Resource

In the Bay Area, historically, many water suppliers have captured rainfall in rural watersheds to fill local reservoirs, but have not captured urban stormwater for water supply. This is poised to change as urban stormwater capture gains momentum: California Governor Gavin Newsom recently directed state agencies to prepare a Water Resilience Portfolio, which explicitly calls to "expand stormwater capture" to reach its "full potential."[9]

The Business Case

Broadly speaking, large stormwater capture projects for water supply are cost effective relative to other new sources, such as seawater desalination and potable water reuse, when they cost about $500-1000/acre-foot ($0.41 – $0.81/cubic meter).[10] These costs for stormwater capture vary considerably depending on local geology and topography.[11] For communities located on the Peninsula needing additional water supply, stormwater capture projects are attractive at even higher costs; the current wholesale rate for water from the San Francisco Public Utilities Commission (SFPUC) is $1,786/acre-foot ($1.45/cubic meter).[12]

Each storm drain system that serves a population of 100,000 or more people (including those of many cities in the Bay Area), and smaller systems that are interrelated with larger entities, must comply with Municipal Separate Storm Sewer System (MS4) permit requirements.[13] Currently, regulations to prevent stormwater from polluting the Bay drive much of the investment in new stormwater infrastructure in the Bay Area. The Regional Watershed Permit mandates Bay Area counties and cities to meet regional Total Maximum Daily Loads (TMDLs) for polychlorinated biphenyls (PCBs), mercury and other pollutants in the Bay resulting from stormwater, which requires significant financial investment in green infrastructure to reduce pollutant loads.

Optimizing stormwater management sites for water capture could encourage opportunities for funding partnerships with water agencies. Green infrastructure for stormwater capture also has the potential to provide multiple benefits that can make it more attractive to communities (e.g., improving surface water quality, mitigating floods, providing habitat, creating opportunities for recreation, and improving urban aesthetics). Though data are sparse and have considerable uncertainty, multiple benefits of green infrastructure for stormwater capture in California can reduce water supply costs by nearly $1000 per acre-foot ($0.81/cubic meter) compared to when these project costs are based on water supply alone.[14]

During a drought, the quantity of potential stormwater available for capture decreases. For stormwater to be available for use when it is most needed, storage in an aquifer, reservoir or large cistern is essential.

McKelvey Ball Park stormwater detention basin in Mountain View, during and after construction

[9] California Natural Resources Agency, California Environmental Protection Agency, and California Department of Food & Agriculture, "Fact Sheet on Water Resilience Portfolio Initiative."

[10] Luthy, Sharvelle, and Dillon, "Urban Stormwater to Enhance Water Supply."

[11] Cooley and Phurisamban, "The Cost of Alternative Water Supply and Efficiency Options in California."

[12] San Francisco Public Utilities Commission, "Rates Schedules & Fees for Water Power and Sewer Service."

[13] California Regional Water Quality Control Board San Francisco Bay Region, "Municipal Regional Stormwater NPDES Permit."

[14] Diringer, Shimabuku, and Cooley, "Economic Evaluation of Stormwater Capture and Its Multiple Benefits in California."

Quarry Lakes, Alameda County (SF Bay Walks)

Stormwater Capture is Not Simple in the San Francisco Bay Area

The Bay Area has strong seasonal precipitation patterns, in which most of the rainfall occurs in winter months when there is the least water demand. Much of the region has clay soils and steep slopes that are not conducive to stormwater capture and infiltration. In many places, shallow groundwater aquifers are not used for water supply, meaning that new infrastructure would be needed to take advantage of water that is infiltrated into aquifers. Surface water storage is possible, but land in the Bay Area is expensive and most of the easy, inexpensive options for surface water storage with or without groundwater recharge have already been developed. Other limitations include concerns about contaminating groundwater aquifers with polluted stormwater, and public concern about pollutants in stormwater accumulating in parks where stormwater capture might occur.

Gravel quarries represent potential opportunities for large-scale storage and infiltration. Alameda County Water District infiltrates stormwater and water from Alameda Creek into the aquifer by way of the Quarry Lakes. Additional gravel quarries in the East Bay exist, such as the Sunol Valley Quarry, but the volume of additional water that can be stored or infiltrated at these sites is small. In terms of surface water storage, existing reservoirs (e.g., Crystal Springs) could potentially be operated to capture stormwater by maintaining lower levels in the winter. However, water managers prefer to maintain the Crystal Springs reservoir full with Sierra snowmelt in wet years; thus, only in dry years when runoff is small might there be excess capacity.

Building-scale rainwater capture in cisterns or rain barrels, in which rainwater is used directly for irrigation or non-potable applications like toilet flushing, is also a possibility in the Bay Area. Given the region's current precipitation patterns, these would have to be quite large and widespread to make a significant dent in water supplies. While building-scale rainwater capture can help new developments meet the stormwater permit requirements, they do not make substantial contributions to water supply during drought years. However, they do present opportunities for public involvement in water management, as well as potentially make good use of early- or late-season rainstorms.

The Bay Area's unique topography and geology precludes some types of stormwater capture. In 2011, BASMAA assessed the feasibility of stormwater capture and storage in the Bay Area by surveying soil types and slopes where infiltration would be feasible. They concluded that about 12% of land in the five counties surveyed contained sandy, silty or loamy soil appropriate for stormwater capture and recharge. Along the bay margin, muddy soils dominate, which have low infiltration rates. Steeper, less developed slopes in the East Bay hills as well as in the Santa Cruz mountains / Peninsula ridges are also not conducive to groundwater recharge.[15]

[15] Geosyntec Consultants, "Harvest and Use, Infiltration and Evapotranspiration Feasibility/Infeasibility Criteria Report."

There may be small pockets of sandier areas adjacent to the Bay, especially near historic streambeds, that are more conducive to infiltration. Site-specific percolation tests may be needed to identify these locations. The greatest potential for infiltration, based on surface soils, is in eastern Contra Costa and Alameda Counties, as well as some areas in Santa Clara Valley. In these areas, depth to groundwater (as well as other feasibility factors such as steep slopes, geotechnical hazards, underlying contamination, and distance to drinking water wells, septic systems, and structures) must also be considered for infiltration feasibility.[16]

Infiltration rates in subsurface soils could vary from surface soils, so it is possible that there are locations where surface infiltration is not feasible, but sub-surface infiltration is feasible. Dry wells for sub-surface infiltration should be located where recharge to the underlying aquifer would be beneficial (which requires input from Sustainable Groundwater Management Act managers), and have sufficient separation to the groundwater table. Often, sub-surface infiltration feasibility must be examined using geotechnical tests in the field. Deep dry wells for infiltration also pose concerns about pollution causing deterioration of groundwater quality.

View of baseball outfield area where stormwater capture facility would be located underground (Town of Atherton)

As an alternative to infiltration, some cities are looking to underground storage in engineered cisterns. For example, the Town of Atherton is proposing to build a 6-10 acre-foot (7,400-12,000 cubic meter) stormwater storage facility under a sports playing field that is owned jointly by Menlo College and Menlo School. The project would be funded by Caltrans and would filter and remove PCBs and mercury from the stormwater as part of its regional permit with the possibility of using the stormwater for irrigation on the sports field and adjacent areas after treatment.[17]

Institutional Barriers Hamper Innovative Solutions

In the Bay Area, stormwater management tends to be handled by entities that have missions related to flood protection or pollution control. Water supply, flood control, and urban parks are all often managed by separate entities, with little opportunity for joint planning, which can complicate development, implementation and shared financing of multi-benefit green infrastructure for stormwater capture. In some cases, stormwater management entities exist within larger organizations that also have a water supply mission (e.g., SFPUC, Valley Water, and Sonoma County Water District) but even there, the management has different organizational structures and funding.

Local funding for stormwater management in the Bay Area is currently quite limited and is already allocated to purposes other than water supply augmentation. Public money must be used for the purpose for which it was originally allocated, and California's Proposition 218 hampered cities' ability to impose fees for municipal services like stormwater control by requiring approval from a majority of property owners, or 2/3 of all voters. This poses a steep hurdle for raising necessary funds for stormwater capture for new purposes like water supply. To be eligible for Proposition 1 funds for stormwater, counties must develop a Stormwater Resource Plan.

[16] Geosyntec Consultants

[17] City of Atherton, "Draft RFP for Cartan Field Stormwater Capture Project."

The Public Appeal

Despite these challenges, stormwater capture and use for water supply in the Bay Area merits consideration. In addition to helping build water system resilience and sustainability, stormwater capture has piqued curiosity and support from members of the public and political leaders. Many people perceive that multi-objective, multi-benefit stormwater management projects can protect water quality in local creeks and the San Francisco Bay, prevent flooding, and also augment water supplies. This means that new stormwater capture projects may receive stronger public support than projects that only contribute to the solution of one problem. Not only are these types of infrastructure projects attractive, voters in other parts of the state have also displayed a willingness to pay for them, as evidenced by the passage of Measure W in Los Angeles that emphasized both clean beaches and a new drinking water source. Locally, voters in Palo Alto passed a stormwater management fee in 2017; program elements include litter reduction, pollution prevention, and constructing green infrastructure to slow, spread, and sink stormwater.

Measure W

In 2018, Los Angeles voters passed Measure W, a tax of 2.5 cents/square foot of impermeable area on each property to fund local projects to capture, treat and use stormwater. The measure required 67% approval to pass, and was approved by 69.5% of voters.

Taking Advantage of Multi-Benefit Project Potential

Despite the challenge of finding appropriate soil types, topography, geology and available land for stormwater infiltration in the Bay Area, some local stormwater management agencies consider water supply when they evaluate the benefits of potential projects. For example, the Santa Clara Basin Stormwater Resource Plan identified thousands of public parcels and tens of thousands of right-of-way segments where green infrastructure for stormwater capture could be located. According to the plan, green infrastructure projects could be designed to meet multiple objectives, including preventing PCBs and other pollutants from contaminating surface waters, re-establishing natural drainage patterns, restoring habitat, and promoting community enhancement. Augmenting local water supply was also included as a potential benefit in the plan, and efforts to articulate the benefits of this aspect of the project could increase its support. The Resource Plan identified twenty-two priority areas for siting green stormwater infrastructure to maximize multiple benefits, and calculated that these priority sites could capture approximately 930 acre-feet (1.1 million cubic meters) of water per year – enough to meet the needs of more than 11,000 residents of Santa Clara County. Other regions of the Bay Area where groundwater contributes to the water supply (e.g., the Tri-Valley area or the City of Pittsburg) may have similar opportunities for such multi-benefit projects.

Multi-benefit infrastructure solutions

State Goals

In recognition of the multiple potential benefits of stormwater capture, the California State Water Resources Control Board recommended that municipal general plans be updated to require consideration of stormwater as a water supply source in their 2018 Stormwater Management Strategy report.[18] In 2019, the California Department of Water Resources set targets for capturing and using 105,000 acre-feet (130 million cubic meters) of urban stormwater in California for direct use and groundwater recharge by 2020 and 250,000 acre-feet (308 million cubic meters) by 2035. These targets were developed based on existing and planned stormwater capture projects across the state. [19]

These targets are motivation for water districts and stormwater managers around the Bay Area to sustain effort on planning and implementing stormwater capture in order to achieve the Bay Area's potential in realizing the state's targets.

Coyote Creek, San Jose (Santa Clara County

Leveraging Existing Infrastructure

Some early stormwater capture and use projects in the Bay Area have largely taken advantage of existing infrastructure. For example, at Stanford University, up to 30 acre-feet/year (37,000 cubic meters/year) of stormwater is captured and pumped to Felt Lake to be used for summer irrigation across campus. This project reimagined a detention basin and pump system designed to prevent hydro-modification of San Francisquito Creek, and realized the advantage of stormwater capture rather than further treatment and discharge to the creek. The stormwater capture project required modifications inside the wet well and different pumping arrangements at small cost compared to the overall stormwater management system.

Another example is a conceptual design for stormwater capture for as much as 10,000 acre-feet/year (12 million cubic meters/year) by diverting runoff from Coyote Creek in San Jose, treating the runoff at an adjacent water recycling facility, and pumping the treated stormwater to existing spreading grounds.[20] This concept takes advantage of the adjacency of the creek and water recycling facility, and underutilized capacity in the spreading basins.

[18] Division of Water Quality State Water Resources Control Board, "Strategy to Optimize Resource Management of Stormwater."

[19] California Department of Water Resources, "Stormwater Targets for Groundwater Recharge and Direct Use in Urban California, Final Report."

[20] Bradshaw and Luthy, "Modeling, Optimization, and Analysis of Water Reuse System Delivering Treated Urban Stormwater to Groundwater Recharge Ponds."

SPOTLIGHT ON INNOVATION

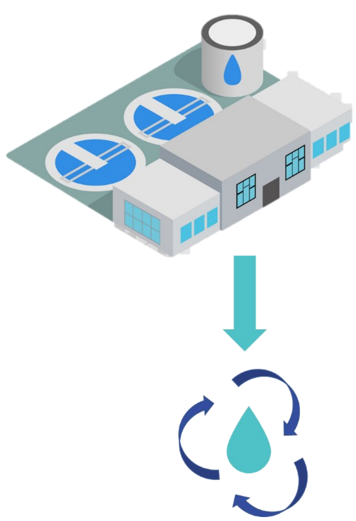
Early adopters of stormwater capture and use are emerging around Northern California. In the Monterey Bay area, a cooperative effort between Monterey and Salinas resulted in Monterey One Water, which treats many different sources of water, including wastewater, agricultural wash water, stormwater, and agricultural runoff for potable and non-potable water uses.[21] The project will leverage existing infrastructure designed to drain agricultural fields and re-direct the flows to their treatment plant, and similarly to collect and treat stormwater from Salinas. Current plans to build potable water reuse facilities in the San Francisco Bay Area may be able to adopt a similar approach for capturing and treating urban stormwater.

In the North Bay, Sonoma County Water Agency plans to capture and bank stormwater underground. Although the project might not be attractive in isolation, the extra water supply that the project provides will be used to meet peak summer demands and eliminate the need for building new, larger-diameter pipes to meet water demand as the population of the region increases. Similar opportunities for local water storage to obviate the need for new pipe installation may exist in the less urbanized parts of the Bay Area that are expecting high population growth in the coming decades (e.g., Livermore Valley).

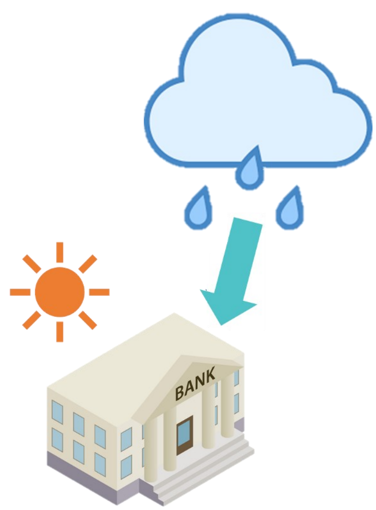
In San Mateo County, joint consideration of parcel-scale, green streets, and neighborhood-scale stormwater capture infrastructure round out a strategy designed for controlling PCBs and mercury pollution to local surface waters. Though not designed specifically for water supply, these green infrastructure projects improve water quality by settling out PCBs and mercury, while infiltrating 240 acre-feet/year (230,000 cubic meters/year) into the aquifer. In addition, the stormwater agencies have forged partnerships with other agencies like Caltrans for funding.

[21] McCullough, "Monterey One Water."

Examples of stormwater capture innovation



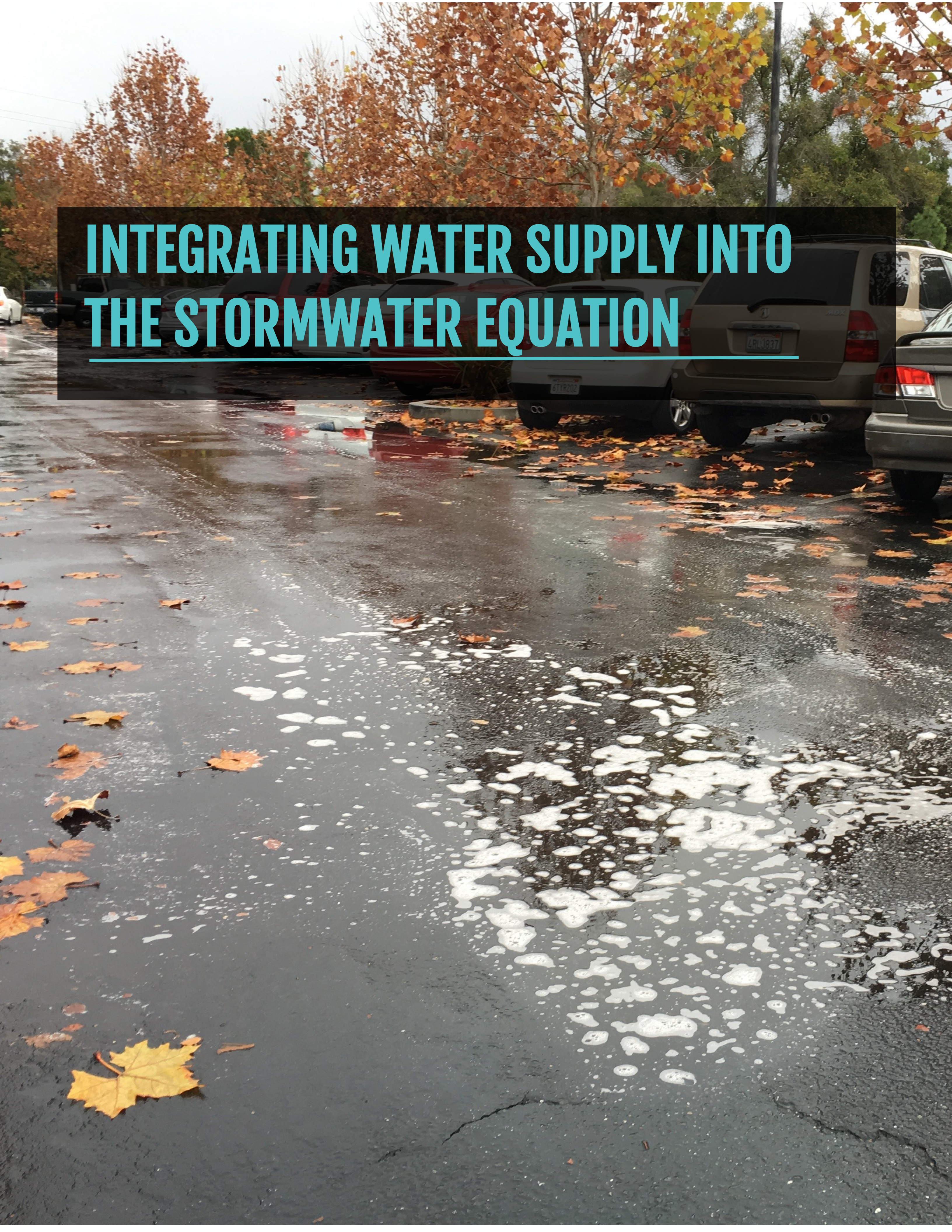
A | **Accepting all types of water, including stormwater, at the treatment plant for reuse**



B | **Banking stormwater to shave peak summer demands and prevent need for new infrastructure construction as the population grows**

C | **Collaborating with external partners for funding**

INTEGRATING WATER SUPPLY INTO THE STORMWATER EQUATION



An Opportunity

The San Francisco Bay Regional Water Quality Control Board's municipal regional stormwater permit requires each municipality to produce a Green Infrastructure Plan by September of 2019. The plans will guide their development of green infrastructure for stormwater capture. Although the permit mainly is concerned with hydro-modification, water quality improvement and prevention of PCB and mercury pollution of surface waters, these stormwater capture features could potentially be designed to meet additional objectives like water supply augmentation. In addition, several Bay Area counties have developed Stormwater Resource Plans to identify specific project opportunities for stormwater capture that can provide multiple benefits, including water supply, to local communities.

Green Infrastructure and Equity

Because green infrastructure for stormwater capture can provide so many local benefits like reduction of flooding and urban green space for recreation, it is important to think carefully about the equity implications of siting such projects. Without focused attention on equity, green stormwater infrastructure features can reinforce existing urban disparities.[22] Spatial tools for promoting equity in siting of green infrastructure exist.[23] At the same time, stormwater managers and city planners acknowledge that improvements in urban green spaces (including green stormwater infrastructure) can result in environmental gentrification, displacing members of the very communities they seek to serve.[24]

[22] Wendel, Downs, and Mihelcic, "Assessing Equitable Access to Urban Green Space."
[23] Heckert and Rosan, "Developing a Green Infrastructure Equity Index to Promote Equity Planning"; Meerow and Newell, [23] "Spatial Planning for Multifunctional Green Infrastructure."
[24] Wolch, Byrne, and Newell, "Urban Green Space, Public Health, and Environmental Justice."

The Possibilities

Increased development of and support for green infrastructure in Bay Area cities opens doors to the possibility of more stormwater capture. Yet building green infrastructure in neighborhoods and city streets is not the only way to capture urban stormwater. Monterey One Water has demonstrated that it can be effective to divert stormwater to treatment plants for centralized recycling. Public enthusiasm for building-scale cisterns may also contribute to the solution if employed in widespread fashion.

Here, we focus on four opportunities for stormwater capture in the Bay Area: large-scale stormwater capture and diversion to a place where it could be infiltrated to groundwater or stored in a reservoir, neighborhood-scale stormwater capture (i.e., parks and ballfields) and green streets, diversion of stormwater to wastewater treatment plants for reuse, and household-scale cisterns and rainwater capture projects.

Opportunities for stormwater capture

Large-scale stormwater capture and diversion

Neighborhood-scale stormwater capture and green streets

Diversion of stormwater to wastewater treatment plants for reuse

Household-scale cisterns and rainwater capture projects

Large-scale stormwater capture and diversion

Large-scale stormwater capture and diversion is appealing because it could potentially contribute significantly to water supplies. Unfortunately, limited opportunities exist in the Bay Area where stormwater can be captured on a large scale and diverted to places where it could be infiltrated to groundwater. The prevalence of clay soils and steep slopes combined with high property values in the region make new installations unrealistic. Re-purposed limestone quarries may be the exception. The Alameda Creek watershed could provide one example of a Bay Area location where stormwater capture and infiltration could be feasible. Another exception may be projects that collect stormwater in sufficient quantities to warrant pumping to places where the water can be infiltrated (e.g., spreading basins). Catchments with an area of good infiltration feasibility (i.e., higher infiltration rates and sufficient separation to groundwater) near the downstream end of a storm drain network could present good opportunities for regional infiltration facilities; site-specific feasibility analysis to identify locations for this type of infrastructure are needed.

Concerns about stormwater causing degradation of groundwater quality also pose a barrier to large-scale stormwater capture and infiltration. However, technologies for treating water prior to or during infiltration (e.g., with passive types of geomedia) are in development and maturing.[25] Further development of low-cost, effective stormwater treatment technologies to remove specific contaminants of concern could help advance the potential for large-scale stormwater capture and diversion.

Neighborhood-scale stormwater capture and green streets

Many opportunities for green stormwater infrastructure at a neighborhood-scale exist in the Bay Area. In addition to the multiple benefits these can be designed to provide, these projects are appealing for water supply because they could capture stormwater for landscape irrigation near a site where it can be used, avoiding the costs and energy requirements of pumping water.

Creating one green infrastructure project or integrating stormwater capture into a single park or playing field will only produce a modest amount of water. From the standpoint of the cost per acre-foot of water recharged, this type of small project might be relatively expensive.[26] Nonetheless, the cumulative impact of multiple projects for augmenting water supplies could be significant, particularly if the projects were implemented systemically during routine street and park upgrades. San Diego has implemented a "One Dig" approach to making multiple upgrades to street infrastructure at once; integrating neighborhood-scale stormwater capture and green streets into similar street infrastructure upgrades in Bay Area cities could serve to make such installations more cost-efficient and less disruptive to neighborhoods.

L: These soccer fields capture runoff from the west side of the Stanford campus. Up to 30 acre-ft per year may be captured and reverse-pumped through the lake water irrigation system to Felt Lake for storage and use during the dry season.

[25] Ashoori et al., "Evaluation of Pilot-Scale Biochar-Amended Woodchip Bioreactors to Remove Nitrate, Metals, and Trace Organic Contaminants from Urban Stormwater Runoff"; Grebel, Charbonnet, and Sedlak, "Oxidation of Organic Contaminants by Manganese Oxide Geomedia for Passive Urban Stormwater Treatment Systems."

[26] Cooley and Phurisamban, "The Cost of Alternative Water Supply and Efficiency Options in California."

Opportunities to capture stormwater for water supply augmentation should also be considered during riparian restoration projects, as businesses build housing for their workers, and while planning for and constructing other new developments. Whether in the public right-of-way or on private land, stormwater capture installations require coalition-building with diverse stakeholders.

Incentives to promote systemic development of neighborhood-scale green infrastructure and green streets for stormwater capture could include raising the stormwater bar of LEED certification, developing regional examples of city codes and model ordinances about green infrastructure for stormwater capture, and providing education for city staff about how to include stormwater capture guidelines in routine infrastructure upgrades. Such guidance is incorporated in the Santa Clara Valley Green Stormwater Infrastructure Handbook, for example.

Green infrastructure in Brisbane and the City of Burlingame for neighborhood-scale stormwater capture and diversion

(Left: City of Brisbane, Above: Matthew Fabry)

Diversion of street runoff to wastewater treatment plants for recycling

Most sewer systems built in the second half of the twentieth century separate stormwater from sewage to avoid the pollution associated with combined sewer overflows. In the Bay Area, only the City of San Francisco employs combined sewers, which largely prevents the use of stormwater unless incorporated in a municipal water reuse program. Although intentional diversion of wet-weather stormwater flows to wastewater treatment plants is impractical, wastewater treatment plants that build water reuse facilities could consider the possibility of capturing dry-weather flows, which are sometimes referred to as "urban drool" (i.e., the nuisance flows from streets, overwatering, sump pumps, springs). Small storms (i.e., less than 1 cm in 24 hours) also could be captured. A treatment system that could accomplish this would have the added benefit of diverting typically pollutant-heavy runoff with high levels of nutrients from entering San Francisco Bay.

Advancing the practice of stormwater diversion to wastewater treatment for recycling requires greater understanding of the opportunities for temporarily piping stormwater into sanitary sewers, assessing the effects of flow and waste strength variability on wastewater treatment process performance, and a better understanding of the contaminants present in dry weather flows. Some assessments of stormwater diversion to wastewater treatment plants for local pollution reduction have occurred,[27] but these have not yet examined the potential for augmenting recycled water supplies.

[27] Santa Clara Valley Water District, "Pilot Urban Runoff Diversion Evaluation: Palo Alto, California"; Bay Area Stormwater Management Agencies Association, "Stormwater Pump Station Diversions Feasibility Evaluation."

Small-scale rainwater capture

Small-scale rainwater capture in households or individual buildings can meet multiple objectives including raising awareness of water systems and spurring public enthusiasm for stormwater management. The cumulative impact of these systems could be significant: assuming there are 2.6 million households in the Bay Area (as per the 2010 Census), and each household can install a 4,999 gallon rainwater tank (connected to a roof downspout) without a permit to be used for outdoor irrigation, that would amount to approximately 40,000 acre-feet of collected water per year. However, it is unlikely (and infeasible) that every Bay Area household would install such large rainwater catchment tanks and use the water regularly. Some water utilities, including San Francisco Public Utilities Commission, have provided rebates for rainwater catchment barrels. Sized at only 50 gallons, these barrels would only add 490 acre-feet of water supply, even if every single household in the Bay Area used one.

Larger cisterns in the Bay Area require special permits, have to meet seismic requirements, and may require building remodels or retrofits to install. This type of stormwater capture is expensive and has not been widely adopted yet in the Bay Area.

Household-scale rain barrel system (Chiot's Run)

During the wet season, household-scale rainwater capture could provide valuable benefits for reducing flooding even if it did not contribute meaningfully to water supply. Household-scale rainwater capture would make the most difference for water supply in years when there are weather anomalies such as fall or spring storms, or relatively dry winters in which landscape irrigation was desired. Climate scientists predict less fog, high year-to-year variability in precipitation, and higher temperatures in the Bay Area in future decades,[28] all of which could cause increased outdoor irrigation needs. These factors would all make systemic implementation of household-scale rainwater capture more viable as a water supply option going forward.

Rainwater tank gauge (Bruce Fulton)

[28] Ackerly et al., "California's Fourth Climate Change Assessment: San Francisco Bay Area Summary Report."

CONCLUSION

The path forward

The Bay Area has great opportunity to increase stormwater capture for water supply augmentation. Regional coordination on stormwater capture can help ensure that advances are made equitably, efficiently, cost-effectively, and maximize multiple benefits.

The path forward for stormwater capture for water supply augmentation in the Bay Area requires attention to several key areas:

- Research and scientific development to answer region-specific questions about stormwater capture, including feasibility, effectiveness of existing projects, and technology improvements (see Appendix B for a list of research needs).
- Development of metrics for meaningful incorporation of co-benefits into decision making about stormwater capture for water supply.
- Assessment of ways in which existing infrastructure may be leveraged to enhance stormwater capture.
- Continued integration of stormwater capture into existing local planning documents like Green Infrastructure Plans, Urban Water Management Plans, urban sustainability and climate resilience plans, and City/County General Plans with FAQs, decision-support and data-sharing tools for city managers and stormwater professionals (see Appendix C for a sample FAQ).
- Analysis of funding options for stormwater capture in the Bay Area with an eye towards innovative partnerships to creatively fund mutually-beneficial projects.
- Expanded capacity of existing groups working on planning and implementing integrated water management to engage with stormwater capture, for example through Integrated Regional Water Management Plans.

Conclusion

Stormwater capture can be part of the transition to more sustainable, resilient water supplies for the Bay Area. This option nests within a larger Bay Area One Water vision of diverse water supply options and integrated water management. As a region home to a diverse, creative, and forward-thinking population, the Bay Area has many opportunities to build from existing local successes and advance stormwater capture regionally.

Stormwater capture is not a panacea for the region's water supply. However, in addition to capitalizing on any large-scale opportunities, small-scale systemic changes in green infrastructure for neighborhood-scale stormwater capture, green streets, and household-scale rainwater capture can add up to a substantial contribution to a resilient water system. Diversifying the water supply portfolio in itself will provide value by offering a range of options in a future defined by decreasing predictability and increasing weather extremes. Reducing the urban heat-island effect, preventing pollutants in stormwater from entering riparian areas and the San Francisco Bay, attenuating flooding, providing wildlife habitat, and contributing to recreational green space are valuable outcomes from smart planning for stormwater management. Additionally, the potential for large-scale stormwater diversion to recycling facilities will grow significantly if Bay Area cities engage in potable water reuse.

All of these opportunities require that our communities consider new ways of managing water systems. Building relationships among stormwater managers regionally and among water and wastewater utilities, stormwater managers, urban planners, regulators, and advocates in local communities can ensure that stormwater capture projects progress most equitably, efficiently, and cost-effectively in the Bay Area.

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APPENDIX A: Workshop Participants

This neighborhood street enhancement project under construction in Redwood City will infiltrate stormwater while enhancing pedestrian safety.

Participants at the Bay Area One Water Network workshop on stormwater capture for augmenting water supplies in the San Francisco Bay Area, held in San Francisco in July 2019.

Hank Ackerman, Alameda County Flood Control and Water Conservation District

Leonard Ash, Alameda County Water District

Neeta Bijoor, Valley Water

Pam Boyle Rodriguez, City of Palo Alto

Joshua Bradt, San Francisco Estuary Partnership

Allison Chan, Save the Bay

Adrian Covert, Bay Area Council

Sarah Diringer, Pacific Institute

Matthew Fabry, San Mateo Countywide Water Pollution Prevention Program

Amparo Flores, Zone 7 Water Agency

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Ben Horenstein, Marin Municipal Water District

Tim Jensen, Contra Costa County Flood Control and Water Conservation District

Steve Jepsen, Southern California Alliance of Publicly Owned Treatment Works

Paula Kehoe, San Francisco Public Utilities Commission

Will Logsdon, San Francisco Public Utilities Commission

Richard Luthy, Stanford University

Vanessa Marcadejas, County of Santa Clara

Mike McCullough, Monterey One Water

Thomas Mumley, San Francisco Bay Regional Water Quality Control Board

Dennis Murphy, Sustainable Silicon Valley

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Tim Potter, Central Contra Costa Sanitary District

Nicole Sandkulla, Bay Area Water Supply and Conservation Agency

David Sedlak, University of California – Berkeley

David Smith, United States Environmental Protection Agency

Michael Thompson, Sonoma County Water Agency

Michael Tognolini, East Bay Municipal Utility District

Ian Wren, San Francisco BayKeeper

Staff support provided by: *Sasha Harris-Lovett (Berkeley Water Center), Molly Mayo (Meridian Institute) and Katie Spahr (Colorado School of Mines)*

APPENDIX B: Data Gaps and Research Needs

This bioinfiltration system infiltrates runoff from the new central energy facility and parking lot at Stanford University

Data gaps and research needs for advancing stormwater capture in the Bay Area

Expand existing efforts to quantify the current stormwater capture opportunity for the nine-county Bay Area

1. Synthesize existing efforts to quantify stormwater capture opportunities from local water supply plans, Stormwater Resource Plans, and the Bay Area Greenprint.
2. How much stormwater capture is possible without harming urban creek ecosystems?
3. How much would capturing different amounts of stormwater cost to build and maintain? How do these costs compare to costs of current stormwater control and stormwater capture requirements for new developments (without water supply augmentation)?
4. How would costs change over time?
5. What is the optimal scale and siting of stormwater capture installations to meet goals for water supply, pollution reduction, and flood control?
6. How does a life-cycle analysis of stormwater capture for water supply compare to other future water supply options like wastewater reuse?
7. How much pollution reduction, flood protection, habitat provision, and improvement in urban aesthetics occur from stormwater capture projects? What other co-benefits of multi-benefit projects could be monitored and quantified (i.e., improvement in property values, recreational opportunities, pedestrian/bicycle safety, greenhouse gas sequestration, green jobs)?
8. If stormwater capture costs were distributed among beneficiaries (water supply, water quality, flood protection), how much would it cost for each?

Estimate the future stormwater capture opportunity for the nine-county Bay Area

1. How do modeled projections of future (2050 and 2100) rainfall patterns, water demands, and floods (including storm surges) affect stormwater capture cost estimates?

Improve stormwater capture technology

1. What are the catchment-scale impacts of different designs of stormwater capture installations on groundwater supply and quality?
2. What are the water quality and quantity impacts of current green infrastructure (not necessarily designed for stormwater capture) on groundwater supplies?
3. What types of in-situ technologies (i.e., soil geomedia) are needed to protect groundwater supplies from contaminants in stormwater?

4. What are the current approaches to addressing contaminant spills in the context of stormwater capture? What improvements are needed to assure groundwater quality and public health?
5. What are the health risks associated with using untreated captured stormwater for irrigation at schools or on public land? What types of technologies can mitigate these risks?

Clarify the regulatory and institutional contexts of stormwater capture

1. Are current stormwater management institutions adequate for stormwater capture? If not, what else is needed?
2. Would stormwater capture violate water rights in any part of the Bay Area? If so, where and how much capture?

Improve messaging, outreach, and community engagement

1. What types of community engagement, outreach, and messaging are most likely to result in support for and legitimacy of stormwater capture projects?
2. In which ways does household-scale rainwater capture contribute to understanding of water systems? Does household-scale rainwater capture encourage reduction or increase in water use?

Advance opportunities for collaboration between stormwater and water recycling/ wastewater managers

1. Which criteria would determine suitability of stormwater diversion to wastewater treatment plants for recycling (i.e., pollutant loads, flows, topography, water recycling technologies in place)? When would stormwater diversion harm wastewater treatment plant operations or inhibit their ability to meet discharge regulations?
2. Which geospatial opportunities exist for diverting stormwater to wastewater treatment plants most cost-effectively (e.g., location of storm drains, wastewater treatment plants, topography)?

Identify funding opportunities

1. What funding opportunities for stormwater capture exist?
2. What are the pathways to increasing funding for stormwater capture?

APPENDIX C: FAQs for City Managers

Pump station for stormwater capture at Stanford University

Sample Frequently Asked Questions about stormwater capture and use for city managers

In which situations is it appropriate to capture and use stormwater? Cities that expect increasing water stress in future decades due to climate change, population growth, and other causes are good candidates for pursuing stormwater capture. Stormwater capture is particularly useful for augmenting water supplies in places where stormwater can either be: 1.) Infiltrated into a groundwater aquifer that is part of water supplies, 2.) Diverted to a water recycling facility for treatment and distribution, 3.) Diverted to a reservoir for storage and eventual use, or 4.) Captured and stored in a cistern for later irrigation use. Household-scale rainwater capture (e.g., in rain barrels) can also help reduce demand for outdoor irrigation water.

Where can stormwater be used? Stormwater can be used to augment water supplies for non-agricultural landscape irrigation without treatment. Stormwater can also contribute to potable water supplies and be used for agricultural irrigation if it is purified to remove contaminants.

Are there concerns about contaminants? If so, which ones? Urban stormwater can contain various contaminants including mercury, PCBs, microplastics (e.g., from car tires), pesticides, oils, and nutrients.

Can contaminated stormwater be treated before it is infiltrated into the groundwater aquifer? Yes. Soil geomedia, such as specially-coated sands, clays or biochar can be used to treat stormwater during the infiltration process. These geomedia can remove trace organic compounds (e.g., pesticides); nutrients; pathogens and metals. [29]

[29] Grebel, Charbonnet, and Sedlak, "Oxidation of Organic Contaminants by Manganese Oxide Geomedia for Passive Urban Stormwater Treatment Systems"; Grebel et al., "Engineered Infiltration Systems for Urban Stormwater Reclamation"; Mohanty et al., "Plenty of Room for Carbon on the Ground"; Ray et al., "Polymer-Clay Composite Geomedia for Sorptive Removal of Trace Organic Compounds and Metals in Urban Stormwater." and Ashoori, N., Teixido, M., Spahr, S., LeFevre, G. H., Sedlak, D. L., & Luthy, R. G. (2019). Evaluation of pilot-scale biochar-amended woodchip bioreactors to remove nitrate, metals, and trace organic contaminants from urban stormwater runoff. *Water Research*, *154*, 1-11."