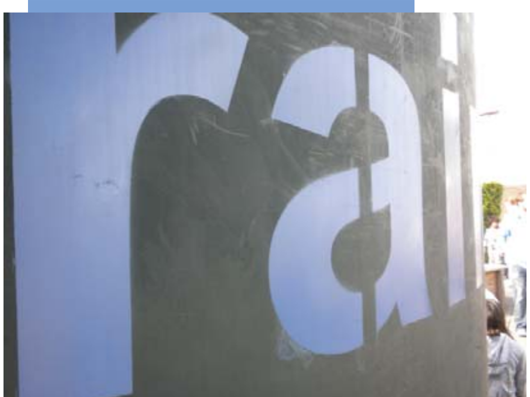
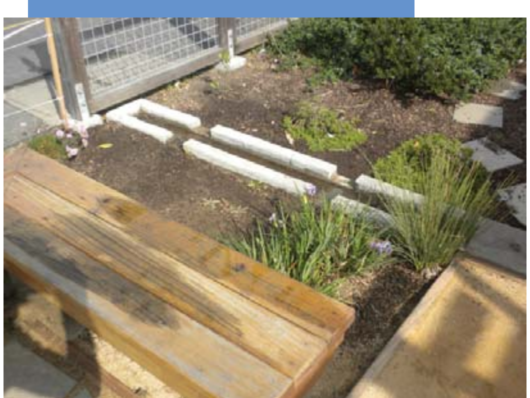
Rainwater Harvesting in San Francisco Schools

Since 2009, one in eight San Francisco Unified School District (SFUSD) elementary schools has received a rainwater cistern or barrels and increased garden space under the Tap the Sky initiative. A quarter of San Francisco elementary schools and two of the city's nine alternative configured schools are planned to have received a cistern system by the end of next year.



This report seeks to identify the impacts and key components of this rainwater capture initiative, both in terms of sustainable water management and environmental education goals, while also suggesting recommendations for the ongoing implementation and expansion of this practice in San Francisco elementary schools.



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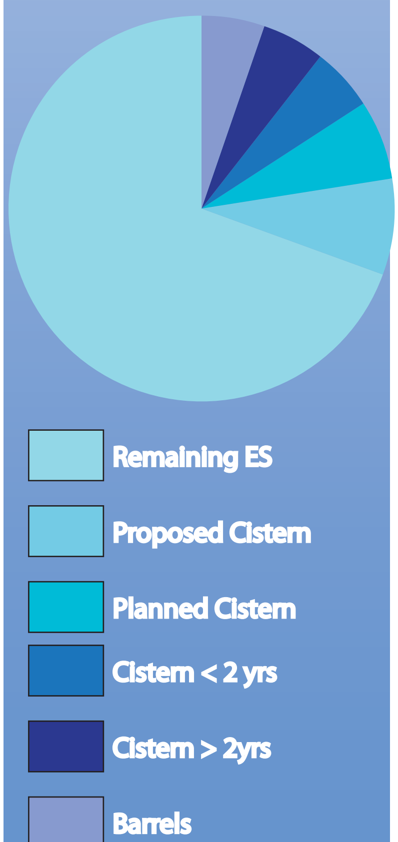
Introduction & Research

Some RWH systems have been installed along with "outdoor classroom" areas such as this one at Starr King Elementary.

Figure 2: Proportion of schools with/out RWH systems as of May



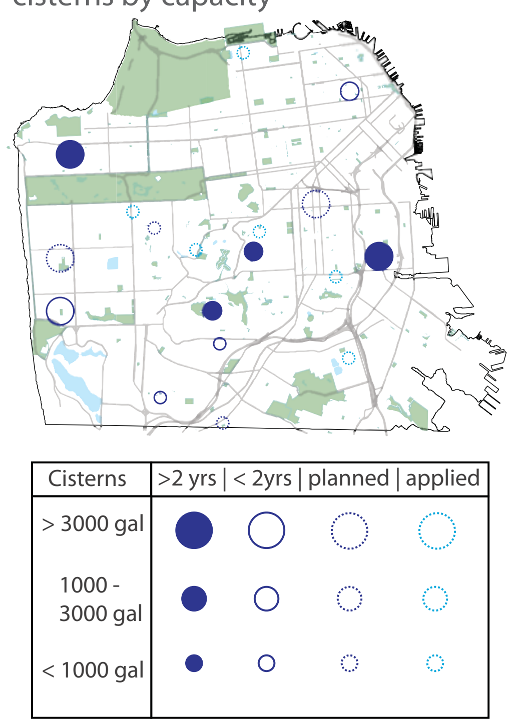
Sources: SFUSD; Green Schoolyard Alliance; Rebuilding Together

The installed and planned rainwater harvesting (RWH) systems are dedicated solely to outdoor irrigation uses at this time. Native plant and food gardens, either preexisting or created along with the RWH installation, are the primary targets for rainwter irrigation. The RWH systems and enhanced garden areas are intended to serve an educational purpose as well.

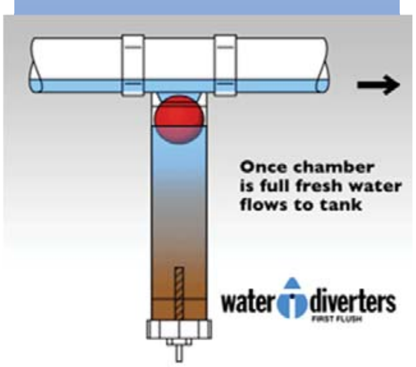
Currently, the number of schools with at least one full water year of use experience (four) is too small to draw firm quantitative conclusions about the use of these cisterns in San Francisco schoolyards. Therefore, this research relied on interviews with SFUSD parents, teachers, and administrators and rainwater catchment practitioners and published articles and resource guides to identify key benefits and concerns with the reuse of rainwater in schools and to suggest recommendations for the expansion and maintenance of these programs.

This research looked at a total of (23) SFUSD elementary schools identified by SFUSD and the Green Schoolyard Alliance (see figure 1). Four of these schools have rainwater barrel systems. As described below, SFUSD has identified a preference for cistern installation instead of barrels, so these schools were not a primary focus of this research. Of the 19 schools that either have or are planned to have a cistern by the end of 2012, four - Lafayette, Miraloma, Alvarado, and Starr King - have had their cisterns in operation for two calendar years. Because the water year runs from October to September, this is the minimum time necessary to observe the use of cisterns through a complete annual water cycle of rainy months (the collection period) and dry months (the usage period). An additional four schools – Jose Ortega, Sunnyside, Ulloa, and Gordon Lau – have had cisterns installed since 2010. Finally, 11 schools are slated for cistern installation by the summer of 2012. Of these schools, six - Longfellow, Stevenson, Alice Fong Yu, Sunset, ER Taylor, and Marshall - are planned, meaning they are slated for installation by fall of 2011. The remaining five schools - Leonard Flynn, Harvey Milk, Claire Lilienthal, Clarendon, and Jefferson – were included in the latest Tap the Sky grant application and will be referred to as the proposed schools. This breakdown is shown in Figure 2, at left. To understand the on-the-ground use experience and planned uses of these cisterns individual interviews with parents and teachers from seven of the nine schools with currently installed cisterns were conducted from mid April to early May 2011.

Figure 1: Existing, planned & proposed cisterns by capacity



Background



Stormwater management can be broadly classified into two major strategies. **Detention** is the strategy of attenuating peak runoff rates by slowing the rate at which runoff reachews the stream or sewer system. **Retention**, in contrast, aims to decrease both the volume and rate of runoff by providing opportunities for stormwater infiltration (the downward entry of water through the soil surface) and evapotranspiration (the combined loss of water from the soil and other wet surfaces due to evaporation and plant transpiration)[1]. **Rainwater harvesting** (RWH; also commonly referred to as rainwater catchment and rainwater capture), is a stormwater management practice that supports both detention and infiltration strategies. Rainwater catchment is simply the practice of collecting rainwater from a hard surface during rain events and storing it for use during dry times. By storing rainwater during rain events, RWH provides peak flow attenuation, thus reducing pressure on San Francisco's combined sewer system[2]. When the stored rainwater is used for irrigation, the water is then allowed to infiltrate into the groundwater table and dissipate through evapotranspiration, thus providing a stormwater retention benefit as well. Finally, the use of stored rainwater in place of treated water from the municipal supply reduces demand on potable water supplies.

RWH requires three essential elements. First, rainwater must be drawn from an identified catchment area, typically a roof. Second, the water must be stored in a cistern or barrel. Barrels typically hold less than 60 gallons while cisterns may hold up to 10,000 gallons or more. While barrels are typically appropriate for a RWH at a single home, cisterns are more efficient when storing water for larger projects. Finally, RWH requires some beneficial use to which the stored water will be applied during dry months. These uses include both outdoor and indoor non-potable uses such as irrigation, toilet flushing, or clothes washing. The catchment area's existing drainage spout is simply diverted to flow into the rainwater cistern while overflow is allowed to spill out into the existing drainage path. Another key feature of rainwater cisterns is the **first-flush diverter**, one design of which is illustrated in figure 2. The diverter allows the first flush of runoff from a rain event to flow to a downspout or chamber which becomes cutoff as the chamber fills. The remaining water from the rain event then flows straight into the cistern. This device provides an important water quality function by keeping the cistern clear of most of the contaminants, particles, and debris that typically wash off in the first flush over the catchment area of any given rain event.

While rainwater harvesting is not new, the incorporation of this practice into San Francisco schoolyards is very recent. Cistern installations at SFUSD schools began in 2009 as part of a remediation campaign undertaken by the San Francisco Public Utilities Commission (SFPUC) in lieu of a fine that had been assessed by USEPA for a combined sewer overflow event[3]. The SFPUC's resulting campaign to reduce impervious cover, such as schoolyard asphalt, and water management education was matched with a de-

1Green Streets, 2002; Start at the Source, 1999

2 San Francisco is one of a handful of American cities to rely on a combined sewer system. In a combined sewer system, both stormwater and household discharges including sewage and greywater are transported, treated, and discharged through the same pipe network.

3 A Combined Sewer Overflow (CSO) refers to the discharge of only partially treated stormwater runoff into a natural water body (in this case San Francisco Bay) from a combined sewer system resulting from a very high intensity rain event. Reducing or eliminating CSOs is one of the primary goals of the SFPUC's comprehensive stormwater management strategy, in which detention and retention play an important part.

SFUSD Rainwater Harvesting Guidelines

Tanks & plumbing should be made of opaque, food-grade platic

Gutter screens and first-flush diverters are required

All spigots need to be labeled "Non-Potable Water - DO NOT DRINK"

The catchment surface should be made of metal or any other non-reactive, non-leaching surface

Rainwater collection will be allowed only from roofs of modular classroom buildings, garden sheds, or other stand-alone structures

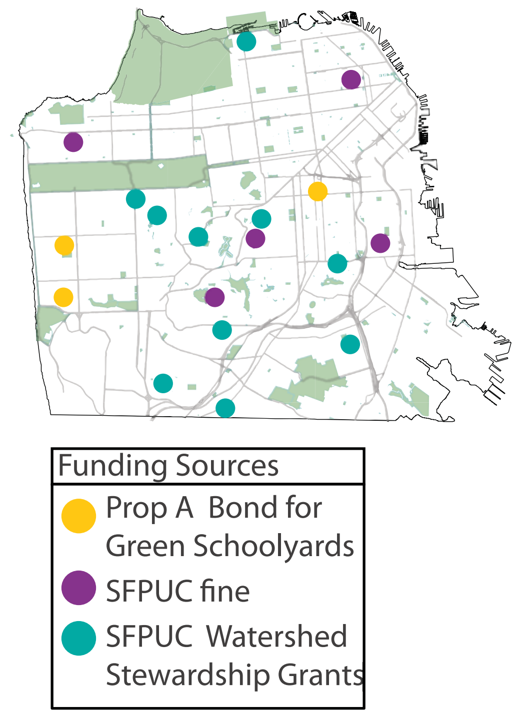
Schools will need to sign an MOU to ensure that seasonal and regulat inspections are performed

sire for more garden space and RWH expressed by several elementary school communities. SFPUC provided $65,000 toward the de-paving and landscaping of portions of schoolyards and the installation of rainwater cisterns at five schools. This effort inspired the launch of SFUSD's Tap the Sky initiative in 2009, which bundles applications for RWH systems into the SFPUC Watershed Stewardship Grant program, a community grant program falling under the wider San Francisco Community Challenge Grants. The 2010 grant of $39,000 has been earmarked for use at five schools and the 2011 grant application for $60,000 has been submitted for use at six additional schools. In addition, funding provided by a 2003 bond approved by San Francisco voters has been used or earmarked for RWH installations at three additional schools. shows the location and funding source of the existing, planned, and proposed cistern projects.

The RWH application process has become more institutionalized in a number of ways since the first round of installations in 2009. First, SFUSD has articulated a clear priority for elementary schools, given the educational advantages of RWH systems as watershed stewardship teaching tools for school children at a formative age. Second, the district has also indicated a preference for cistern-based systems rather than those using a series of connected rain barrels due to a perceived greater cost-effectiveness and typically lower maintenance needs of single cistern systems.

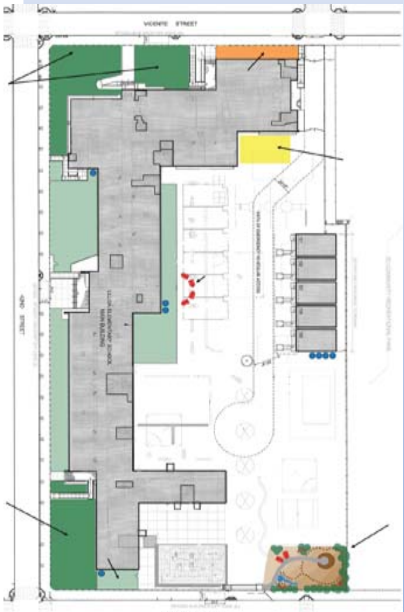
Third, the district adopted the **Rainwater Harvesting Guidelines** in early 2010 (Guidelines highlights are presented at left). The Guidelines outline several structural and material parameters for applicant systems, including first-flush diverters.

Figure 3: Cistern Funding Sources



The Guidelines also limit permitted catchment areas to roofs of **modular classroom units** (commonly referred to as bungalows or portables), garden sheds, or other stand-alone structures. This policy is intended to provide school staff and district administration the chance to gain experience with RWH systems without taking on the greater maintenance liability of installing systems near main school buildings. As will be discussed below, this policy has important implications for both quality and quantity of stored rainwater at the schools.

Rainwater Use & Education



While the application process has become more standardized through the Guidelines, the ongoing use of the cisterns after installation remains largely decentralized and untracked. There is currently no standard monitoring system in place to track the levels to which cisterns are being filled, the amount of stored water being used, or the use to which stored water is being applied. However, the application process outlined in the Guidelines does attempt to anticipate such information by requiring Tap the Sky applicants to describe the intended uses of the proposed RWH system as well as how the water will be transported from catchment area to ultimate use and how the system will be maintained. The Guidelines also provide for site audits by the Green Schoolyard Alliance to determine the best size and location of the cistern. Plans and guidelines, though, never guarantee that ongoing operations will continue according to plan. Therefore, this research attempted to better understand the use of existing cisterns through direct interviews.

First, the interviews focused on the quantitative experience and immediate plans for rainwater use. The usage experience of the four schools with a full water year of use ranged from almost no use at all to watering almost all the pre-existing planters at the school, beyond the areas de-paved at installation. Unfortunately, two of the four were unable to share real use experience due to the choice by one school not to significantly use the water out of quality concerns (to be discussed in more detail below) and an incident at another school where nearly the entire cistern was drained through the spigot in a single night just before the dry season either out of negligence or malice. This cistern has since installed a lock on the cistern spigot. The experience from the other two longest standing systems indicated that their 3,000 and 1,500 gal cisterns, respectively, met their intended watering needs last summer and are expected to again this summer. To estimate the usage potential of each school, Table 1 shows an existing capacity to usage ratio based on the size of the intended irrigation areas and cistern volume for the nine schools for which this information was obtained.

Table 1: Existing & Planned Capacity to Usage Ratios

SCHOOL	CAPACITY (gal)	IRRIGATED AREA (ft^2)	CAPACITY/USAGE (gal/ft^2)
Alvarado	2115	424	10.4
Gordon Lau	2410	500	10.4
Jose Ortega	620	185	3.4
Lafayette	3000	448	6.7
Marshall	3000	630	4.8
Miraloma	1500	144	10.4
Starr King	3000	570	5.3
Sunset	3000	1096	2.7
Ulloa	5500	2400	2.3

Source: interviews with SFUSD parents and teachers April - May 2011

In qualitative terms, interviewees indicated that the current and intended uses of the stored rainwater are largely consistent across all schools, ranging from solely non-edible plantings to various combinations of butterfly gardens, ornamental flower beds running long the perimeters of the school, edible fruits and vegetables in raised planters and ground beds, herb gardens, native trees, and in once case a small orchard area. In all but two cases, cisterns are drawing off of bungalow roofs. The two exceptions are one pre-Guidelines school where the catchment area is a portion of the roof of a secondary building on the campus and one school drawing from a greenhouse, which is consistent with the Guidelines.

Second, parents and teachers felt across the board that the inclusion of the cisterns and enhanced garden areas or "outdoor classroom" facilities has been a major asset for environmental education at the schools. Nonetheless, the management and educational programming of the garden spaces varied substantially from school to school. Most notably, three schools have used privately-raised funds by the PTA to hire a gardening teacher to maintain and supply the garden and oversee garden-based lessons with the students. Two schools have provided for a part-time teacher and one school has secured a full-time garden teacher. At a fourth school, a full-time classroom teacher has taken on the garden management and teaching duties. In all other cases, parent volunteers organized through the PTA perform garden maintenance.

At the schools without a gardening teacher or designated classroom teacher, the integration of the new gardens and RWH systems into the school's educational programming appears to be limited. This is partly because parent volunteers are prohibited from leading student lessons without a teaching certification, though some schools have organized afterschool gardening clubs where parents can perform some garden-based education. Even at the schools with a gardening teacher, the extent to which the RWH system is featured in lesson plans is dependent upon the comfort level of individual classroom teachers in an outdoor teaching environment and the teachers' knowledge of gardening. Furthermore, the state curriculum standards were also cited by interviewees as both an opportunity and a hindrance to water and gardening education. While the pressure on classroom teachers to meet testing standards appears to discourage many teachers from including water and gardening in their lesson plans, the state curriculum's environmental and biological units appear complimentary to the RWH and garden projects.

Where gardening teachers are in place, a strong effort has been made to provide hands-on experience with the RWH systems and gardens to as many students as possible. Activities have included watering various planting areas by the students using buckets filled from the cisterns, native plant identification exercises, herb and fresh produce tastings, and seedling exercises watered by rainwater. In addition, these teachers expressed varying levels of familiarity with the Watershed Stewardship Curriculum prepared by the Green Schoolyard Alliance, with the general consensus being that the Curriculum was helpful for classroom teachers seeking to include water conservation principles into their lesson plans, but less critical for

the gardening teachers who are experts in the subject matter and typically have their own lesson plans. Finally, students are exposed to the RWH systems on a daily basis across the board as the cisterns are typically located in the schoolyard areas where students take recess. Given this continuous proximity, the informational signage and clear labeling of the cisterns as outlined under the Guidelines are critical to the systems' educational impact.

Key Concerns

The interviews identified roughly two categories of concerns over RWH in the schools where it has been incorporated. First, there are the concerns surrounding the ongoing **maintenance and educational utility** of the RWH and garden sites. As mentioned, the lack of funding for gardening teachers and the pressures of the stat curriculum limit the ability of classroom teachers to effectively feature water stewardship and gardening education. Also, although schools are required to assume responsibility for annual maintenance of the cisterns and adopt a community-led maintenance plan at the time of application, a volunteer-dependent maintenance strategy is inherently limited, especially as parents come and go with their students. Furthermore, all funding for garden upkeep and materials (including such essentials as good topsoil and seeds) is currently provided by the PTA. The tenuous garden management system as it stands threatens the long-term usefulness of the RWH systems themselves.

Secondly, and potentially of greatest concern, were the concerns over **water quality** raised by a few interviewees. Currently, the District Guidelines outline material standards aimed at minimizing potential health risk such as the requirement that cisterns draw only from non-leaching or non-reactive roofing surfaces, the suggestion that all piping be assembled of food-grade HDPE and the requirement that all spigots be labeled as non-potable.

To scrutinize these standards more closely, two recent studies on the contamination effects of various roofing materials were reviewed[4]. The studies suggest that, while concerns over quality from various roofing materials are not unfounded, that the risk from selected roofing materials, including coated galvanized steel, is not likely to be substantially greater than the background risk for uncollected rainwater (i.e. rainwater that falls directly on the irrigated area) or to exceed USEPA non-potable urban water reuse guidelines. Between the studies, two major findings stand out. First, coated galvanized steel roofing, concrete tiles, and "cool roofs" remain the best options for most quality standards[5]. Second, first flush diverter systems are essential to achieving most tested quality standards. In particular, the study testing the coated galvanized metal product, Galvalume ®, found that after a first flush this material was the only one of those tested to meet the USEPA non-potable urban water reuse guideline for fecal coliform, yielded a dissolved oxygen content (DOC) level indistinguishable from the ambient sample level and met USEPA primary or secondary drinking water standards for all six metals tested (aluminum, zinc, lead, arsenic, copper, and iron)[6]. Meanwhile, the study testing uncoated galvanized steel produced largely consistent findings, but found that zinc levels in rainwater

4 Mendez et al, 2010; Nocholson et al, 2009

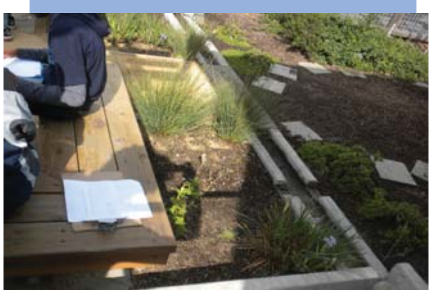
5 Mendez et al, 2010

6 ibid

drawn from uncoated galvanized steel can potentially exceed USEPA secondary drinking water standards[7]. The reports concur that fiberglass asphalt shingles and uncoated galvanized steel roofing are generally unacceptable for rainwater catchment and diverge on the quality implications of drawing from a green roof system.

While neither of these studies can guarantee the complete safety of rainwater use for non-potable applications, they certainly suggest that the health risk is minimal from coated galvanized steel, concrete tiles, and cool roofs and support the safety, plumbing, and material standards laid out in the SFUSD Rainwater Harvesting Guidelines.

Rainwater Supply & Demand



To suggest a quantitative reference for better matching cistern size to the intended irrigated area, the following figures were produced using the below rainwater supply and irrigation demand equations provided by the ARCSA[8] and Reference Evapotranspiration Map provided by CIMIS[9].

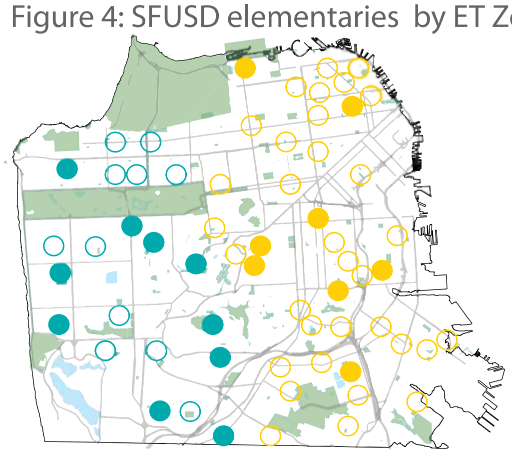
ET refers to annual reference evapotranspiration, or the amount of water in inches lost on average for a given region from evaporation and plant transpiration. ET is then multiplied by a plant coefficient, ranging from 0.2 to 0.5 to 0.75 for low, medium, and high water use plants, respectively, to account for the water intensity of various planting options. San Francisco falls into two ET zones, according to CIMIS, which generally correlate to typical fog intensity. Figure 4 shows the approximate ET zone of all San Francisco elementary schools. Zone 1 schools should use an adjusted ET[10] of 28 in and Zone 2 schools should use 33in. Similarly, annual precipitation averages from both the Oceanside and Downtown NOAA weather station records from 1971 – 2000 were used to identify an annual precipitation amount of 18 in for Zone 1 and 21 in for Zone 2 . Finally, a plant coefficient range of 0.2 to 0.5 was used owing to the constant focus of all interviewees on low-water use and drought-tolerant plants for school gardens.

SUPPLY (gal) = rainfall (in) x 0.623* x catchment area (ft2) x runoff coefficient**

DEMAND (gal) = demand ET (in) x plant coefficient x 0.623 x irrigated area (ft2)

* This is a conversion from inches to gal/ft2
** The runoff coefficient for sheet metal is 0.95

Figure 4: SFUSD elementaries by ET Zone



7 Nicholson et al, 2009

8 Porter et al. *Rainwater Harvesting.* American Rainwater Catchment Systems Association, 2008.

9 Hannigan. *Reference Evapotranspiration Map.* California Irrigation Management & Information System (CIMIS), California Department of Water Resources, 1999

10 This paper adjusted the ET figures from the annual amounts of 33 and 39 in for Zones 1 and 2, respectively, in order to exclude the three wettest months of the San Francisco year (Jan – Mar) when cisterns will typically recharge rather than discharge.

Table 2: Existing & Planned Supply per ft² vs. Expected Demand per ft²			
SCHOOL	ACTUAL SUPPLY (gal/ft²)	EXPECTED DEMAND (gal/ft²)	ADEQUACY
Alvarado	10.4	4.1 - 10.3	over
Gordon Lau	10.4	4.1 - 10.3	over
Jose Ortega	3.4	3.5 - 8.7	under
Lafayette	6.7	4.1 - 10.3	adequate
Marshall	4.8	3.5 - 8.7	adequate
Miraloma	10.4	3.5 - 8.7	over
Starr King	5.3	4.1 - 10.3	adequate
Sunset	2.7	3.5 - 8.7	under
Ulloa	2.3	3.5 - 8.7	under
Source: Table 1 values, ARCSA rainwater supply & demand equations			

First, using these assumptions, Table 2 (above) compares the actual supply per sq ft of irrigated area from Table 1 to the expected demand range derived using the ARCSA equations. This table compares the actual supply per sq ft of irrigated area to the expected demand per sq ft of irrigated area on an annual basis and finds that most schools have installed an adequately sized cistern to meet their current irrigation needs, while three (3) schools do not appear to currently have sufficient cistern capacity for their intended irrigation needs.

Second, the standard modular classroom dimensions of 24x40 ft were used as inputs for the supply equation to generate a guide, represented in Table 3 below that schools may easily reference to get a rough idea of the irrigated area supported by their intended catchment area[11].

While the sizes of systems are currently determined by funding and space limitations, providing schools a tool to roughly estimate a reasonable irrigated area per catchment size would a) allow schools to evaluate whether installing a RWH system will achieve community objectives and b) identity the gap between what available funding allows and the cost of a system that would meet the desired demand so that fundraising goals may be accurately set. This tool could also be easily tweaked to allow schools to visualize the water demand and cistern size implications of altering the water intensity of the intended landscaping elements.

Table 3: Water Demand met by Catchment Area				
ET ZONE	WATER INTENSITY	DEMAND (gal/ft²)	SUPPLY (gal)	DEMAND MET (ft²)
			per 1/2 bungalow	*per bungalow*
1	*low*	3.5	5113.6	1461.0
	med	8.7	5965.8	685.7
2	*low*	4.1	10227.2	2494.4
	med	10.3	11931.7	1158.4
Source:				

11 "½ bungalow" refers to RWH drawing from only one half of the total roof area of the bungalow. This has been typical, as the bungalow roofs are pitched, making it easiest to draw from just one side.

9|9

Recomendations & Conclusions

1. Expansion of RWH to future schools should remain driven by community demand
2. Fund District-level gardening teachers where possible and offer RWH teaching workshops for classroom teachers
3. Focus on rainwater use for non-edible application and avoid spray watering edibles to address quality concerns
4. Employ quantitative methods, like ARCSA equations, to better match cistern capacity with irrigation demand
5. Explore indoor non-potable rainwater applications, like toilet flushing, to substantially decrease potable water usage

First, the District should to maintain the current demand-based application approach for expanding RWH systems to further schools. Pursuing RWH systems only in schools where there is enough interest from parents and teachers to generate a Tap the Sky application will help ensure that systems will only be installed at schools with the volunteer capacity to maintain and promote these systems adequately.

Second, hiring District-level gardening teachers to tend small groups of RWH gardens and sponsoring occasional workshops for classroom teachers to highligh the RWH systems and gardens as a teaching resource to meet state environmental unit curriculum standards would enhance the educational utility of the systems. Providing gardening teachers where possible and encouraging classroom teachers to take advantage of these systems is critical to integrating water stewardship principles into schools' educational programs.

Third, where water quality concerns persist, two simple approaches can be adopted. One is to use stored rainwater exclusively for non-edible applications; the other, where edibles are being watered from the cisterns, is to water the soil directly or use a drip irrigation system rather than spray water the plants. The District could also help minimize quality concerns by ensuring that all cisterns are complying with the guidelines on clear labeling of the cisterns as a non-potable water source and perhaps conducting an inventory of roofing materials and roof age.

Fourth, adequate and efficient use can be ensured by using ARCSA methods to estimate adequate supply to demand ratios and base cistern size and planted area on such quantitative methods. Sharing resources such as SFPUC's low-water use guides for plant selection can also help maximize efficient use of rainwater.

Finally, the gross amount of water savings potentially achievable through Tap the Sky is very small in comparison to total city water usage. If the average cistern size from currently installed, planned, and proposed schools (1,600 gal) were extrapolated to all remaining SF elementary schools and alternative configured schools, the amount of water detained in SFUSD RWH cisterns would amount to less than a 100th of a percent of the city's total annual water usage[12]. If the District or school communities were to identify substantial reductions in the use of potable water as a RWH goal, the application of RWH to interior non-potable applications, such as toilet flushing, would have to be considered. For instance, the Australian municipality of Kogarah, in the Sydney metropolitan region installed large RWH systems at all 22 of its schools and achieved up to 70% reductions in potable water use for irrigation and toilet flushing[13].

Ultimately, RWH systems of any size in schoolyards are most impactful as an educational benefit to students and the larger school community and should be primarily evaluated in this light. The prominent integration of these systems into the school community helps build the social and political will to pursue the more complex and expensive solutions, such as interior RWH applications and greywater and recycled water systems, that will become increasingly necessary in a water scarce future.

12 Urban Watershed Management Plan, 2005
13 Chanan et al, 2010

Works Cited & Acknowledgements

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Phone interviews were conducted from April 11 to May 5, 2011 with SFUSD elementary school parents & teachers, who will remain anonymous. The following additional phone, in-person, and email interviews were conducted:

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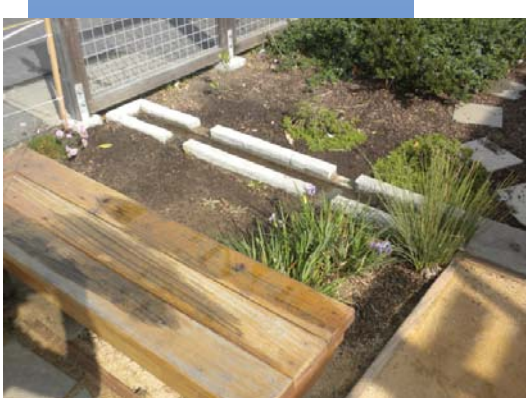

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