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Memorandum

Date: 11 March 2009

To: Joseph Edwards, Scot Scialpi, and Sat Tamaribuchi

From: Eric Strecker, Aaron Poresky, and Daniel Christensen

Subject: Rainwater harvesting and reuse scenarios and cost considerations

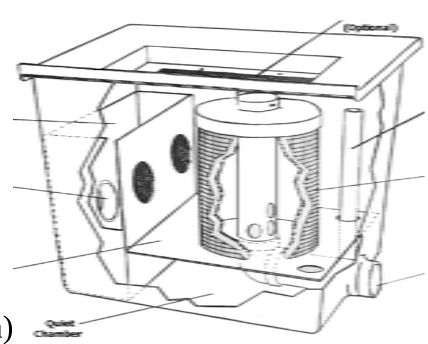
The purpose of this memo was to investigate two hypothetical scenarios involving rainwater harvesting and reuse in residential neighborhoods in Orange County, California. These scenarios include an on-lot harvesting and re-use and community-scale harvesting and re-use. The community system was also modeled to assess its potential benefits using some simplifying assumptions. Finally, general findings are presented in a brief summary.

BACKGROUND

Stormwater storage and re-use is a general description referring to the capture and storage of runoff and subsequent re-use of that water. Such a system could take a variety of forms. In the case of urban residential development, the typical storage component consists of some form of an enclosed tank or “cistern” that accepts runoff from roof drains or neighborhood storm drains. Some level of treatment (e.g. screening, filtration, etc.) is typically required upstream of the cistern to prevent the introduction of debris into the system. In addition, some form of treatment would be required, depending on the planned use. Potential re-use demands in residential neighborhoods are generally limited to irrigation of lawns and landscaped areas and/or to meet non-potable demands in homes such as toilet/urinal flushing (EPA 2008). The list below outlines the general materials needed for a reuse system for a single family household.

- Downspouts/Piping to Cistern: Typically a cistern is located near or directly under the downspout and minimal piping is needed. However, if driveway, patio and walkway water is to be collected on a lot, then additional collection and piping systems would be needed. The tank in this case would likely require deeper burial to be able to accept ground level runoff.
- Collection Filters: Fine mesh can be placed over the downspouts to prevent debris from clogging gutters and downspouts and entering the cistern. Filters with finer particle extraction capability, also known as “roof washers”, can also be placed at top of the downspout to filter finer particles. (Figure 1a). For inlets from other areas such as driveways, filter materials can be integrated with the inlet and in fact would be more critical than for downspouts as debris quantities would be expected to be larger from ground level.

- First flush diverter: Typically this is a vertical pipe located before the cistern that traps the first flush volume using a ball float helping to prevent built-up contaminants entering the tank. The length and size of the vertical pipe determine the amount of water that will be diverted. A weep hole at the bottom of the vertical pipe empties the trapped first flush water. (Figure 1b). Another option would be to allow the tank to fill and then either divert via an overflow in the incoming pipe system or via a tank overflow.
- Tank/Cistern: Structure receives and stores impervious runoff (typically from roofs) and is design to store a certain volume of runoff to meet water use demands. (Figure 2a)
- Insect tank screens: Any open entrance to the tank should be covered with a fine mesh insect screen to prevent mosquitoes and pests from entering the cistern. (Figure 2b)
- Pump: A pump is used to force water to treatment system as appropriate and then toilets and/or irrigation system.
- UV treatment: Some regulations may require UV treatment for indoor non-potable water reuse or if water is re-introduced into a pressurized irrigation system. Another option would be to have a separate non-pressurized (low-pressure) irrigation system.
- Piping: Additional pipelines (purple lines) inside the house and to the irrigation system are needed to ensure the non-potable water does not mix with potable water.
- Backflow valve: This valve is a safety measure to ensure non-potable water does not mix with the potable water lines. An air-gap may also be used or in addition to a backflow valve.
- Potable water use failsafe system: A potable water line should be in place as a backup in case the non-potable reuse system fails or empties. This requires a double-line system and all measures should be taken to prevent non-potable water from mixing with potable water lines.
- Stencils: All non-potable water outlets should be clearly labeled as a “non-potable” source.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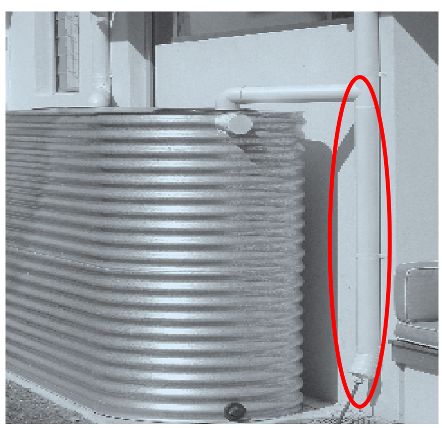
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Figure 1. a) Downspout filter or “roof washer”; b) First Flush Diverter

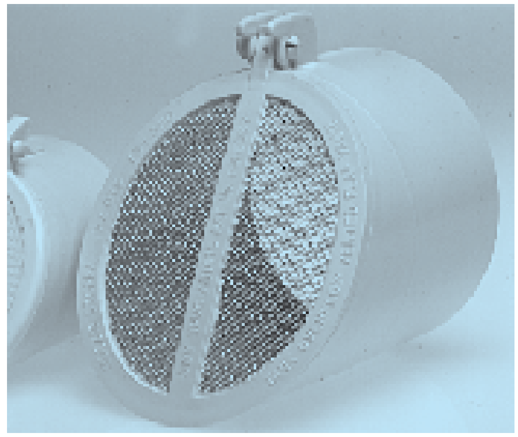
a)  b) 

Figure 2. a) Cisterns; b) Insect screen

The critical factor in performance of storage and re-use systems lies in the integration of the magnitude and pattern of inflows and outflows with storage volume. For example, if inflow and outflow are well-matched and fairly constant, the system will require a small storage volume. If inflows and outflows are well-matched in total volume but come at different times, a larger storage volume may be required to match supply with demand. In the case of storage and re-use as a means of "disconnecting" impervious area, the most important requirement is that cistern has sufficient capacity and ability to regenerate this capacity, such that the system captures a significant portion of runoff on an average annual basis. If demand for harvested water during the period of high runoff is small compared to the overall runoff volume, then the system may not be able to perform its intended function of capturing a significant volume of runoff.

Two scenarios that were used for a general analysis are presented below. The first is a single family home scenario and the second is a 100-acre residential development. For the single family home scenario, two situations are analyzed: 1) only runoff from the roof-top drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern. For the 100-acre residential development, runoff from the entire catchment, including the streets, sidewalks, driveways and roofs and pervious area was considered. The second scenario was also modeled using SWMM to ascertain long-term hydrology benefits.

HYPOTHETICAL SINGLE HOUSEHOLD SCENARIO

A simple single household example of rainwater harvest and reuse is provided to outline rough estimates of water demand and tank drawdown times that could be expected from a typical reuse system on a residential lot found in Orange County. This analysis uses the simple rational method to calculate runoff volumes and require tank size following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP. Runoff coefficients dependent on imperviousness found in the DAMP document were used in the runoff calculations. A total lot area of 0.1 acres with 69% impervious area was assumed. This imperviousness is based on 2,400 sq ft of roof area, 600 sq ft of other impervious area (driveway, sidewalks and patio), and the remaining 1,356 sq ft of pervious area. A rainfall depth of 0.8" was used to size storage units. This depth represents approximately the 85^{th} percentile, 24 hour rainfall depth for large parts of Orange County. Two storage rainwater collection and storage scenarios were analyzed: 1) only runoff from the roof of the house drains to the cistern, and 2) runoff from the roof and additional impervious areas (driveway and patio) drains to the cistern.

Two reuse demand scenarios were considered: 1) reuse for internal demand only (i.e. toilet flushing), and 2) reuse for internal and external (i.e. irrigation) demand combined. Demand for toilet flushing and outdoor use per household were assumed to be 65 gal/day and 77 gal/day, respectively. The estimate for toilet flushing use was derived from an estimate of 18.5 gal/person/day (AWWARF 1999) and an assumed average occupancy of 3.5 people per house. For outdoor demand, the average use rate for May, September and December was estimated to be 113 gal/day for 2000 square feet of landscape area in the Irvine region (IRWD 2009). Since the majority of rain in Orange County occurs between November and March, the average of May, September and December demand likely over-estimates the demand for harvested rainwater during the months when rainwater is available for harvesting. The average demand was scaled to the assumed 1,356 sq ft pervious area per lot used in this study, yielding 77 gal/household/day.

Based on the capture and storage scenarios and re-use scenarios described above, approximate average drawdown rates were estimated. Drawdown rates are important to the performance of stormwater BMPs because they affect how much storage capacity can be regenerated to capture runoff in subsequent storms. Table 1 shows the characteristics of the hypothetical lot and resulting cistern volume and drawdown times.

Per the calculations reported in Table 1, the drawdown time of a household cistern is expected to range from approximately 8 to 21 days. Note that these calculations assume that outdoor demand is immediately present following a storm event; likely an over-estimate due to rainfall soaking of landscaped areas and the prevalence of back-to-back storms in Southern California. From a runoff reduction perspective, a user would like to empty the cistern relatively quickly so that adequate storage is available for the next storm. Conversely, from a water reuse perspective, a user would likely desire the tank to empty slowly so that demand could be met for a longer period with the captured stormwater.

Table 1: Single household rainwater harvesting system attributes used for analyses.

	Roof Runoff	Roof + Other Impervious area	
Lot Characteristics			
# houses	1	1	
Total lot area	0.1	0.1	acres
Impervious area of roof	2400	2400	ft2
Other impervious area	600	600	ft2
Pervious area	1356	1356	ft2
% total impervious area of lot	69%	69%	
% of impervious area to cistern	80%	100%	
Runoff Coeff. for impervious area	0.9	0.9	
Storage Tank Sizing			
Storm Depth	0.8	0.8	inches
Vol Cistern	144	180	ft^3
	1,077	1,346	gal
	0.0033	0.0041	acre-ft
Demand Calculations			
People/ house	3.5	3.5	
Toilet use/capita	18.5	18.5	gal / day
Toilet use/house	65	65	gal / day
Outdoor / house	77	77	gal / day
Drawdown Times			
Toilets only	17	21	days
Both Toilets & Outdoor uses[1]	7.6	9.5	days

[1] Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

HYPOTHETICAL 100 ACRE NEIGHBORHOOD SCENARIO

A neighborhood example of rainwater harvest and reuse is provided to outline rough estimates water demand and tank/basin drawdown time that could be expected from a larger centralized reuse system found in Orange County that would capture runoff from the entire catchment (including streets, driveways, and pervious areas if they are contributing). This analysis uses the simple rational method to calculate the runoff to size the volume for storage system following the methods outlined in the "New Development and Significant Redevelopment" chapter in the DAMP 2003 to size the cistern volume. A total tributary area of 100 acres with 60% impervious area was assumed. Assuming the same 0.1-acre lots as above at a density of 4.5 du/ac, the total acreage covered by residential lots would be 45 acres. This leaves approximately 27.5 ac of roads and 27.5 ac of common areas, parks and open space to yield 60 percent neighborhood-wide imperviousness.. Based on 1,356 sf of pervious area per lot and 450 lots in the neighborhood, 14 acres of pervious area would be located on private lots and the remaining 36 acres of pervious area would be contained in parks, open space, and greenways. A rainfall depth of 0.8" was used to size the neighborhood storage unit as this depth represents approximately the 85th percentile, 24 hour rainfall depth for large parts of Orange County.

The same water demand estimates as the lot scenario were used to develop the neighborhood scenario. Off-lot pervious area was assumed to be irrigated at the same rate per square foot as on-lot pervious area. Table 2 shows the characteristics of the neighborhood tributary area and resulting cistern volume and drawdown times.

Table 2: Neighborhood rainwater harvesting system attributes used for analysis.

Tributary Area Characteristics		
# houses	450	
Impervious area	60	acres
Pervious area	40	acres
% impervious	60%	
Composite Runoff Coeff. C	0.60	
Storage Tank Sizing		
Storm Depth	0.8	Inches
Cistern / Basin Volume	174,000	ft^3
	1,300,000	Gal
	4.00	acre*ft
Reuse Demand Calculations		
People per house	3.5	
Toilet use per capita	18.5	gal / day
Toilet use per house	65	gal/ day
Outdoor demand per 2000 sf of pervious area	113	gal / day
Total toilet demand	29250	gal / day
Total outdoor irrigation demand	98500	gal / day
Total toilet + irrigation demand	127750	gal / day
Drawdown Time		
For Toilets	45	Days
Both Toilets & Outdoor[2]	10	Days

BASIC COST CONSIDERATIONS

Cisterns may take a variety of shapes and forms, thus costs may vary substantially by project. Likewise, the appurtenances required to convey water to the tank and supply the building demand are likely to be affected by project-specific factors. Finally, there are a variety of treatment systems that could be considered. Therefore, only a rough estimate of costs for storage and re-use can be made herein. The basic cost items that will be considered include: collection tanks, filters, UV treatment, 1st flush diverters, inlet piping and filters; pumps and appurtenances; the incremental cost of a dual plumbing system, and installation. The limited implementation of storage and re-use systems of the sort being considered herein allows limited basis for comparison to actual projects. Table 3 shows an itemized cost list for rainfall harvesting items.

[2] Outdoor assumes that irrigation demand is immediate; more sophisticated modeling could be completed to more accurately characterize irrigation demand, but for purposes of this analyses, it has been assumed to be immediate. This likely significantly overstates the demand for irrigation.

Table 3: Rainwater harvesting items and prices

Item	Description	Cost	Reference/Source
TANKS			
Galvanized steel	200 gal	$225	Fairfax County, 2005
Polyethylene	165 gal	$160	Fairfax County, 2005
Fiberglass	350 gal	$660	Fairfax County, 2005
Plastic	800 gal	$400	Plastic-mart.com
Plastic	1100 gal	$550	Plastic-mart.com
Plastic	1350	$600	Plastic-mart.com
Plastic cone	1500 gal w/metal stand	$1500	Plastic-mart.com
Plastic	2500 gal	$900	Plastic-mart.com
Plastic	5000 gal	$3000	Plastic-mart.com
Plastic	10000 gal	$6000	Plastic-mart.com
Dry Det. Basin(1997)[3]	$C = 12.4V^{0.760}$: for 1 ac-ft	$41,600	stormwatercenter.net
Below Ground Vault[4]	$C = 38.1\ (V / 0.02832)^{0.6816}$	$55,300	fhwa.dot.gov
Concrete	1,000,000 gal above g. (O&P)	$548,000	RSMeans
Steel	1,000,000 gal above g. (O&P)	$467,000	RSMeans
TREATMENT			
UV (house-scale)	Whole system - 12 gpm	$700-$900	rainwatercollection.com
UV bulb	Life: 10,000 hrs or 14 months	$80-$110	rainwatercollection.com
UV (neighborhood-scale)	Whole system - 200 gpm	$10,000	Bigbrandwater.com
Downspout filter	Placed in Gutter	$20 - $500	many online
1st Flush Diverter	Vertical pipe w/ ball float	$50-$100	raintankdepot.com
PUMP	1 hp (all in one package)	$575 - varies	rainwatercollection.com
PIPING (Purple)			
to Tank (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to House (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to Tank (neighbor.)	Concrete: 6” – 18” (O&P)	$15-$30 /LF	RSMeans
to House (neighbor.)	HDPE- 4” – 10” (O&P)	$11-$27 / LF	RSMeans
to Irrigation	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans

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[3] This dry detention cost equation is based on Brown and Schueler, 1997, where C is the construction, design and permitting cost and V is the volume (cu-ft) need to control the 10-year design storm. In this case, the 0.8” storm runoff volume was used in place of the 10-yr design storm volume.

[4] This below ground storage vault equation is based on Weigand et al., 1986, where C is the construction cost estimate in 1995 dollars and V is the runoff volume (cubic meters) of the maximum design event frequency, taken to be the 0.8” storm for this study.

Item	Description	Cost	Reference/Source
Backflow prev. valve	Each	\$100-\$200	web
STENCILS	Non-potable water	----	
INSTALLATION	Percentage of material cost	40 % – 50%	

A rough cost estimate for the hypothetical examples can be developed using the table above. Table 4 summarizes the potential costs for the single household (lot), and Table 5 summarizes the potential costs for neighborhood. For the neighborhood scenario, the pipe (purple) lengths were estimated using measurements along the centerline of streets from a similar size neighborhood in Irvine.

According to Table 4, the total cost of the single household rainwater harvest and reuse system would be approximately \$4900. The total cost for the neighborhood scenario is approximately \$1.65 million. This would equate to roughly \$3660 per house, most of the saving being found in the total cost of the tanks verse a large central storage unit. A case study posted on the City of Portland's website provides a cost estimate for a built rainwater harvesting system for a farm house which totaled approximately \$5,400, excluding the cost of the cistern (Portland 2009).

Table 4: Rainwater harvesting materials cost for single household scenario

Item	Description	Cost
TANKS		
Plastic	1100 gal and 1350 gal	\$550
TREATMENT		
UV	Whole system - 12 gpm	\$800
UV bulb	Life: 10,000 hrs or 14 months	\$80-\$110
Downspout filter	Placed in Gutter	\$250
1st FLUSH DIVERTER	Vertical pipe w/ ball float	\$100
PUMP	1 hp (all in one package)	\$575
PIPING (Purple)		
to Tank (lot)	PVC: 2"-6" (O&P) 20ft	\$8 / LF
to House (lot)	PVC: 2"-6" (O&P) 50ft	\$8/ LF
to Irrigation	PVC: 2"-6" (O&P) 50ft	\$8 / LF
Backflow prev. valve	each	\$200
STENCILS	Non-potable water	----
INSTALLATION	40% of material cost	\$1400
TOTAL		**\$4,900**

Table 5: Rainwater harvesting materials cost for neighborhood scenario

Item	Description	Cost	Units Assumed
TANKS			
Dry Det. Basin(1997)	$C = 12.4V^{0.760}$	$119,000	174,000ft^3
Below Ground Vault	$C = 38.1\ (V / 0.02832)^{0.6816}$	$142,000	174,000ft^3
TREATMENT			
UV - neighborhood	Whole system - 200 gpm	$10000	
Catch basin filters	1 every 2 acres	$2000	50 catch basins
PUMP		$50,000	
PIPING (Purple)			
to Tank (neighbor.)	Concrete: 6” – 18” (O&P)	$15-$30 /LF	$23 - 14000 ft
to House (neighbor.)	HDPE- 4” – 10” (O&P)	$11-$27 / LF	$19 - 14000 ft
to Irrigation	PVC: 2”-6” (O&P)	$2-$12 / LF	$8 - 60 ft /house
Backflow prev. valve	each	$100-$200	$200 per house
STENCILS	Non-potable water	----	
INSTALLATION	40% of material cost	$470,000	
TOTAL		**$1,650,000**	

Note that there would also be on-going operation and maintenance costs for operation of both neighborhood and on-lot systems. These costs would include electricity, filter maintenance, operator for the neighborhood system, on-going training for home operators or contract maintenance and other on-going costs (periodic replacements/repairs, etc.).

ASSESSMENT OF HYDROLOGIC IMPACTS OF CISTERNS FOR NEIGHBORHOOD SCALE

Four community-scale residential re-use scenarios were analyzed based upon the above description of the 100-acre residential catchment. The four scenarios included:

A. Storage sized for 0.8” storm event and water reuse for toilet flushing only,
B. Storage sized for 0.8” storm event and water reuse for toilet flushing and outdoor uses,
C. Storage sized for 1.6” storm event and water reuse for toilet flushing only,
D. Storage sized for 1.6” storm event and water reuse for toilet flushing and outdoor uses,

Each scenario was modeled over a long period to better understand the potential hydrology performance of runoff storage and re-use systems in Orange County, California. Simplified representations were used for catchment runoff, cistern storage and re-use demands from toilet flushing and irrigation.

The Laguna Beach rainfall gage was used as a representative rainfall record for large parts of Orange County. The Laguna Beach gauging station is located in the City of Laguna Beach. The gauge elevation is 210 ft above mean sea level (AMSL). Reuse demand inputs were generated from IRWD estimates of indoor demand and irrigation demand. Results of this effort include the overall stormwater capture efficiency achieved in each scenario and the portion of residential demand that could be supplied by rainwater harvesting (RH).

METHODOLOGY

This section describes the methodology used to estimate system performance.

Model Selection

The EPA Stormwater Management Model (SWMM) Version 5.0 was used for continuous simulation analysis of the various facility configurations. SWMM is a dynamic rainfall-runoff simulation model used for single event or continuous simulation of runoff from primarily urban areas. The model accounts for various hydrologic processes that combined to produce stormwater runoff from urban areas. The model also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures (USEPA, 2008). SWMM was selected because of its proven capabilities in simulation of urban hydrology and hydraulics, and its flexibility in representing the proposed systems. Although in this case, SWMM was used with some simplifying assumptions, it could be used with in a more sophisticated modeling approach to account for such factors as irrigation demand based upon available evapotranspiration rates, etc. that would allow for a more accurate analysis of irrigation demand then conducted in this simplified analysis.

Model Input Parameters

Table 6 shows the input parameters used to represent the tributary area to the re-use facilities. In addition, information from Tables 1 and 2 was used to characterize the attributes of each of the scenarios.

Table 6. Baseline SWMM Inputs - Hydrology

Parameter	Value	Units	Source/Rationale
Rainfall	Laguna 2 NCDC record (1952-1993)	in/hr	Representative of rainfall pattern at project locations; long period of record; good resolution; minimal missing data
Imperviousness	60	%	Consistent with hypothetical scenarios described in memo.
Slope	0.03	ft/ft	Includes roofs, lawns, streets, and sidewalks.
Impervious Roughness	0.01	-	Literature[1] (not sensitive to analysis)
Pervious Roughness	0.1	-	Literature[1] (not sensitive to analysis)
Impervious Depression Storage	0.02	inches	Literature[1] (sensitive to analysis, selected conservatively)
Pervious Depression Storage	0.10	inches	Literature[1] (sensitive to analysis, selected conservatively)
Ksat	0.15	in/hr	Literature[1] (representative of B/C soils) (moderately sensitive to analysis
IMD	0.25	in/in	Literature[1] (representative of B/C soils) (moderately sensitive to analysis, not highly variable)
Suction Head	8	inches	Literature[1] (representative of B/C soils) (not sensitive to analysis)
% of Imp area w/o DS	25%	-	SWMM default (moderately sensitive to analysis)
Path Length	500	ft	Typical of urban development
Routing	Imp and Perv routed directly to outlet	-	Conservative representation; in reality some imperviousness will be routed over pervious area, resulting in diminished volumes for small storm events
Dry Weather Flow	Assumed to be zero	cfs	Based on use of efficient irrigation methods

1 – Based on James and James, 2000.

Hydrology Validation

Average annual runoff coefficients recommended by the OC DAMP Table A-1 were compared to model results. For 60% impervious areas, the DAMP Table 1 recommends a runoff coefficient of 0.60. The SWMM model computed a long-term runoff coefficient of 0.58. This is believed to be adequately close for the purposes of this analysis.

Facility Representation

The storage and re-use systems were simulated as a simple underground storage feature (zero evapotranspiration) with multiple outlets to represent various types of re-use demand. The following assumptions were used:

- Storage volume was simulated per the hypothetical scenarios described in the memo. The baseline design storm depth was 0.8 inches for calculating the size of the storage facility. A scenario was also simulated that included twice as much storage (i.e. a 1.6 inch design storm).
- Toilet flushing was assumed to be the only indoor demand for harvested rainwater and was simulated as a constant use rate. It is acknowledged that toilet flushing will exert a time-dependent demand, most notably on a daily patter, however average rates were deemed acceptable for the modeling effort given the time scale of facility drawdown being considered (greater than 5 days).
- Irrigation demand was assumed to be constant within a single day, but to vary seasonally based on irrigation use data from IRWD's website (Table 2). The simulations did not account for reduced irrigation demands following wet periods that likely would significantly extend the storage drawdown times for irrigation use. Therefore, this analysis likely over predicts the effectiveness of the system in reducing runoff when irrigation is included.

Table 2: Landscape irrigation rates by month for IRWD service area (IRWD)

Month	Gal/mo per 2000 sf of landscaping	Gal/day per 2,000 sf of landscaping
Mar	3000	100
July	7500	250
Sept	5300	177
Dec	1900	63

Irrigation demand was interpolated between the monthly averages from Table 2 to yield monthly average values. The same yearly pattern of irrigation demand was assumed through the entire simulation period, though it is acknowledged that irrigation demand will vary by year (as well as following wet periods).

- An overflow weir was simulated to represent the condition in which the cistern is full and additional runoff bypasses the facility.

The simulation was run for 1952 through 1993 at 15-minute computational timesteps and one-hour reporting steps. Cumulative volumes were totaled and processed.

SUMMARY OF RESULTS

Table 3 provides a summary of key inputs and results for 42 years of continuous simulation.

Table 3: Key Inputs and Results

Key Inputs and Results	Units	Scenario A: Toilet Flushing Only, 0.8" design storm	Scenario B: Toilet Flushing + Irrigation, 0.8" design storm	Scenario C: Toilet Flushing Only, 1.6" design storm	Scenario D: Toilet Flushing + Irrigation, 1.6" design storm
Design Storm for Tank Volume	inches	0.8	0.8	1.6	1.6
Tank Volume	cf | ac-ft | MG	174,000 | 4.0 | 1.3		348,000 | 8.0| 2.6	
Indoor Use Rate	cfs | gpd	0.0428 | 27,700			
Avg Ann Outdoor Use Rate (varies by month)	cfs | gpd	-	0.195 | 126,000	-	0.195 | 126,000
Average Annual Drawdown Time	days	47	8.5	94	17
Average Stormwater % Capture	%	32%	55%	41%	68%
Avg % of Indoor Non-potable Demand Satisfied	%	52%	NA	65%	NA
Avg % of Outdoor + Indoor Non-potable Demand Satisfied	%	NA	16%	NA	20%
Avg % of Total Residential Demand Satisfied	%	6.2%	11%	7.8%	13%

DISCUSSION

The modeling results illustrate several key concepts:

- Capture efficiency increases with higher use rate and larger volumes. Higher use rate serves to make more volume available for subsequent storms, while larger volume allows more water to be stored for use after the wet season.
- The percentage of the residential demand that can be satisfied using runoff capture and reuse is both a function of the use rate and the amount stored.

- The overall reduction of demand for potable water from systems designed to capture the DAMP volume are on the order of 6 to 11 percent (more likely closer to 6-8% due optimistic irrigation demand assumptions)
- The amount of runoff captured on an average annual basis by a DAMP sized cistern and re-used is on the order of 30 to 55%, likely closer to the 30 to 40 percent range due to optimistic irrigation demand assumptions. Therefore if no other treatment of runoff was provided, the system would leave about 60 to 70 percent of runoff untreated.
- Doubling the tanks size increases the percent capture, but at much less of a rate then the increase in size of the storage volume (i.e. double the volume with about a 10 percentage point increase in percent capture).
- Although the single lot scenario was not modeled, due to the fact that it does not include streets, the percent capture of runoff from a neighborhood with on-lot systems would be less overall than the community scenario.

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