

Harvesting Rain: Addressing Water Needs of the Monterey Peninsula

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By: Bryce Kantz

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Abstract

This Capstone addresses the need to supplant 9,626 acre-feet of Carmel Valley ground water overdrafted annually by the California American Water Company (Cal-Am). WR 95-10 and the 2008 Cease and Desist Order currently under litigation by the State Water Resources Control Board (SWCRB) require that the Carmel Aquifer water in overdraft be replaced by a reliable and sustainable source. Rain water harvesting is an internationally proven technology utilized to augment water supplies in dry regions. If this technology were adopted in Monterey, how much water could be captured within the Cal-Am service area?

Utilizing ArcGIS, this study has found the total square footage of rooftops within the Cal-Am service area to be 1.84 square miles or 1179 acres. Statistical analysis of a fifty eight year rain record determined that between 14.6” and 17.3” of rainfall on the Monterey Peninsula annually. Ninety five percent of the time, between 1434 acre feet and 1700 acre feet of fresh water will fall on the rooftops of buildings within the Cal-Am service area annually.

The total volume of water capturable forced acceptance of the null hypothesis, rooftop rainwater collection does not replace the 9,626 acre-feet of water in overdraft by Cal-Am. However, even in a dry year 15% of the water overdrafted by Cal-Am could be harvested and put to use by MPWMD users.

Introduction

California Water Supply Context

Human civilization requires a clean, reliable, and sustainable source of fresh water. The raised Greek and Roman aqueducts of the past have been replaced by modern day networks of canals, lift stations, pipes, and wells.

Two massive water transportation networks (the Central Valley Project – CVP, and State Water Project – SWP) redistribute rainwater and snow melt from its origins in Northern California, to the agricultural and population centers in Central and Southern California. At the times of the SWP and CVP inceptions, Monterey Bay communities were not included in the service area. Geographical concerns about water delivery (pumping water over the coastal range would be quite expensive), and limited demand meant that the communities of Monterey Bay were on their own to provide for the future of their fresh water supplies (USBR 2009) (DWR 2009).

Monterey's Groundwater History

Providing fresh water to the residents of the Monterey Peninsula has been a difficult issue of resource management. Prior to the 1940's Cal-Am provided water to the residents of Monterey County based on the supplies stored in the San Clemente Reservoir located in the upper reaches of the Carmel River watershed (Kemp, unknown).

Post-1940 demand exceeded the San Clemente's 2,140 acre-feet of storage capacity, which due to sedimentation has been steadily declining (WR 95-10). Since 1940 Cal-Am has drilled twenty one wells along the extent of the Carmel River watershed tapping the Carmel Aquifer (figure 1). Currently these wells are utilized to withdraw

14,000 acre feet of water annually, the majority of which is provided to customers outside of the Carmel River watershed.

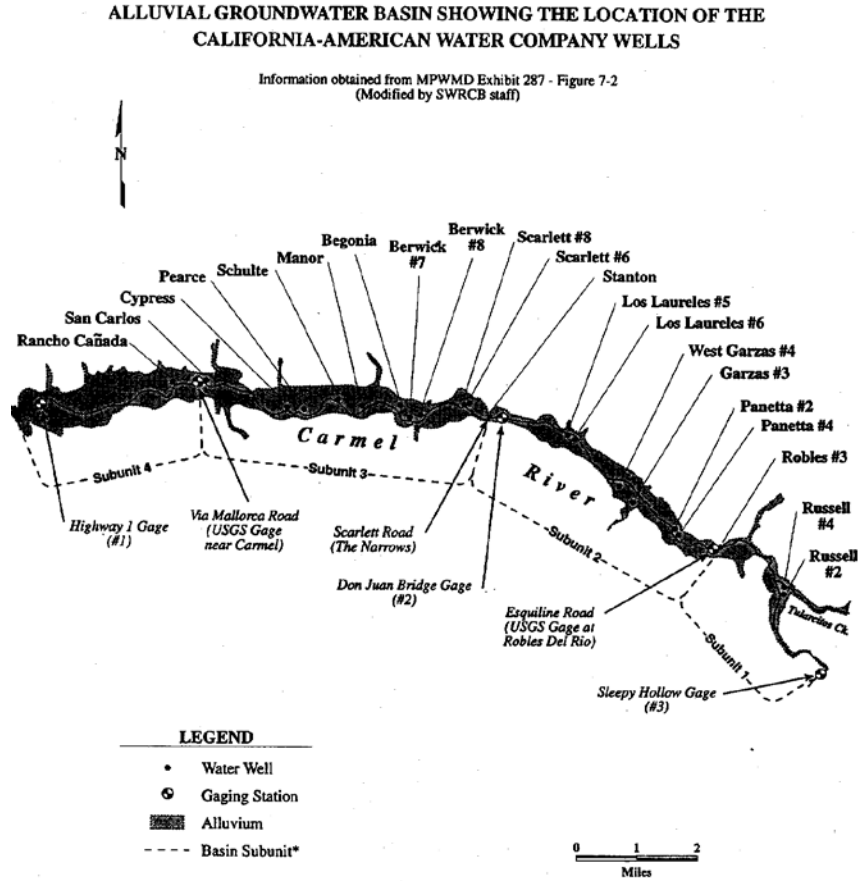


Figure 1: Well locations report prepared for the SWRCB 95-10 order

Late in the 1960's homeowners living near Cal-Am wellheads in Garland Park and Robinson Canyon noticed that the riparian vegetation was dying. In response to environmental deterioration observed, the Carmel Property Owners Association hired a consultant to investigate the cause. The study determined that due to ground water pumping the water table surrounding Cal-Am wellheads had dropped. Falling water tables caused the desiccation of vegetation around the wells and throughout the riparian corridor. Cal-Am hired their own consultant who provided data to the contrary, claiming

the withdrawals had sped up the natural succession of the plants within the ecosystem (Kondolf and Curry 1984). Regardless of the conflicting findings of the consultants, it was clear that through their pumping Cal-Am was impacting the Carmel River ecosystem.

State Water Board Decision WR 95-10

Between 1987 and 1991 the State Water Resources Control Board (SWRCB) received formal complaints from four stakeholder organizations within the Carmel Valley: the Carmel River Steelhead Association, the Sierra Club, the Residents Water Committee, and the California Department of Parks and Recreation. Complaints alleged that pumping of the Carmel River Aquifer by Cal-Am:

- Caused observable recession of the Carmel River riparian zone,
- Was Destroying habitat for the then threatened post 1998 endangered Steelhead Salmon, and
- Violated the public trust doctrine – stating that the harvesting of a public resource (Carmel River water) must not interfere with the ability of the public to utilize that resource.

In 1995 the SWRCB upheld the allegations of the Carmel River stakeholder groups, determining that Cal-Am had no legal right to 10,730 acre-feet of the 14,000 drafted annually (WR 95-10, 2008).

Order WR 95-10 included a mitigation plan requiring that Cal-Am reduce the amount pumped from the Carmel River via a series of options. These options included: appropriating/purchasing legal rights to the water in overdraft, greater reliance on the nearby Seaside Aquifer, building of a new dam, and/or exploration of alternative and

renewable sources of fresh water such as desalination and waste water treatment (WR 95-10, 2008).

The SWRCB options have been explored by Monterey County voters, Cal-Am, and the Monterey Peninsula Water Management District (MPWMD, the County regulatory body which oversees the actions of Cal-Am). In 1995 the new Los Padres Dam project designed to contain 24,000 acre feet of water was turned down by voters due to both environmental and aesthetic concerns (MPWMD, 2004). A pilot desalination facility was installed in Moss Landing on the Duke Energy power plant grounds. However, results of the cost to yield study caused the MPWMD board to vote down the full scale Sand City desalination plant (Hennessey, 2004). Cal-Am shifted as much reliance onto the Seaside aquifer as possible, pumping 5,600 acre-feet of water from the basin per year. In April of 2005, the Yates Report determined that the safe yield for the Seaside Basin was 2,880 acre-feet per year (safe meaning sustainable, a situation in which withdrawal from the aquifer by pumps does not exceed the natural recharge rate). Shifting reliance from the Carmel Aquifer to the Seaside Basin (a SWRCB WR 95-10 recommendation) by Cal-Am caused the only other available Monterey groundwater resource to go into overdraft.

Present MPWMD Problem

Since 1995 Cal-Am and the MPWMD have attempted to pursue the stipulations put forth in WR 95-10. Post 2000 these efforts have resulted in the reduction of Carmel Aquifer overdrafts from 10,370 acre-feet to 9,626 acre-feet (Jackson 08) (Community Leader Workshop 2008), however diversions out of the Carmel River have continued and environmental problems have grown. The Carmel River watershed and its associated

aquifer (figure 2) are the current source for 69% of the water provided by Cal-Am to the MPWMD service area (figure 3) (WR 95-10, 2008).

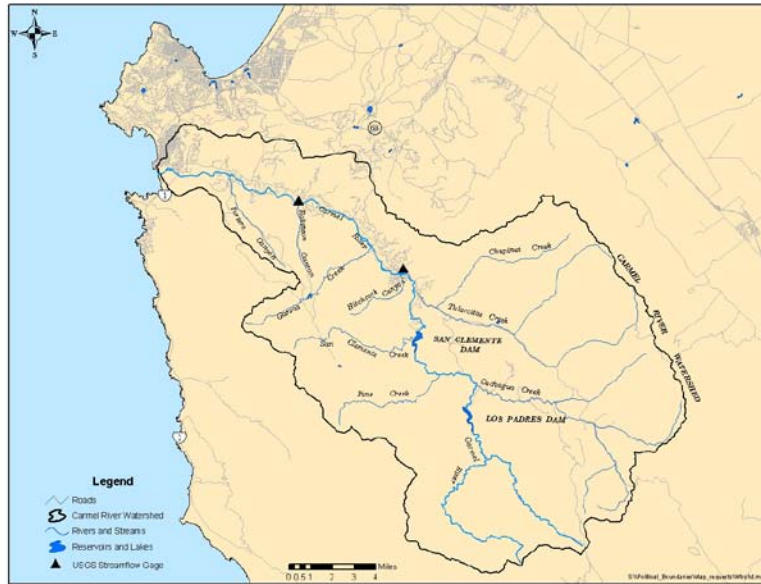


Figure 2: Carmel River watershed.

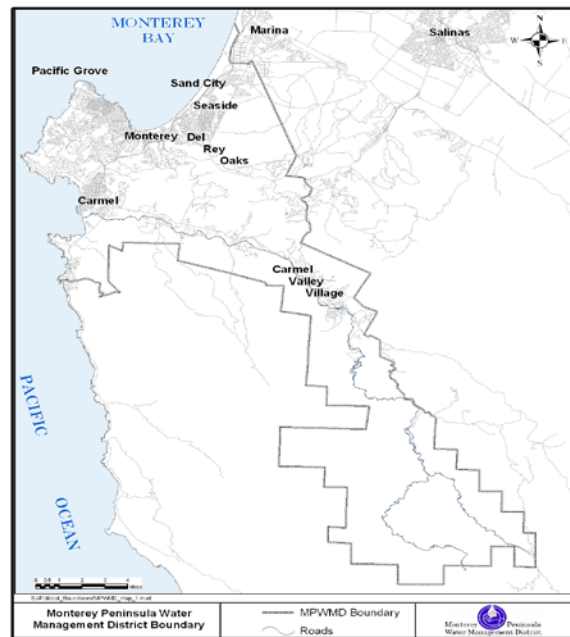


Figure 3: MPWMD / Cal-Am service area. Note the similarity to the delineation of the Carmel watershed

In 1998 Cal-Am's overdrafting dried the Carmel River for the first time during the spawning season of the native and threatened Steelhead. Prevention of access to Steelhead habitat resulted in the Federal elevation of the Steelhead's status from threatened to endangered. For the first time regional public interest (outside the Carmel Valley) was focused on the plight of the Carmel River and its aquifer.

Stakeholders

Many stakeholders are involved in the resolution the Carmel River Cal-Am overdrafting dilemma. Cal-Am is under contract with MPWMD to provide water to the district users. Home owners and sport fishers in the Carmel Valley are concerned about deteriorating environmental conditions. The California Department of Water Resources and SWRCB are under pressure from the Endangered Species Act (and its Federal enforcers) to mitigate the overdrafting. All of these groups want to alleviate the problem, yet no viable replacement for the 9,626 acre-feet of Carmel Aquifer water has gained approval from voters, the State, or Cal-Am.

As result of Cal-Am's inability to meet the water diversion reduction goals set forth in WR 95-10, the SWRCB has been forced to take action again. In 2008 a Draft Cease and Desist Order (DCDO or CDO) was filed by the SWRCB requiring that Cal-Am reduce water diversions to 1995 levels by 2010 (reductions will continue to the point that diversions reach 50% of 1995 levels by 2014) or face legal action on the part of the Attorney General, six digit fines, and a tiered seven level water rationing schedule for the entirety of the MPWMD district (DCDO 2008).

Quantification of the Monterey Peninsula Rainwater Resource

Throughout the world rainwater harvesting has become a successful method to augment the supply of water limited communities (Texas Guide to rainwater Harvesting). Many governmental bodies offer rebate programs for households which are capturing and storing rainwater. San Francisco and Pacific Grove offer rebates in which payments are based upon the total storage capacity of the subsidized cistern (White, 2009). Some desert communities have gone a step further. For example Victoria and New South Wales, Australia, have enacted legislation which requires the installation of rainwater catchments and storage systems on all new buildings constructed within their jurisdiction (Rain Harvesting 2009).

Monterey Peninsula needs a set of sustainable fresh water sources that will combine to meet freshwater needs. As shown above, rain water collection is a proven technology currently meeting fresh water demand in communities around the globe. In considering alternative sources of fresh water for Monterey County Cal-Am and the MPWMD policy makers have not thoroughly investigated all the resources represented by the citizens of Monterey and the rainwater which falls on them. This Capstone investigation represents a preliminary quantification of the amount of rainwater which can be harvested from rooftops within the MPWMD.

For the purpose of scientific inquiry Capstone, I hypothesize that more than 9,626 acre-feet of water can be collected annually from rooftops within the MPWMD service area. Alternatively, results of this study could prove the null hypothesis; that not enough water falls on roofs within the MPWMD service area to offset overdrafting of the Carmel

River. The null hypothesis will be rejected if the entirety of the 95% confidence interval lies above 9,626 acre-feet of harvestable rainwater.

Based on the results of the study, recommendations will be made with the goal of alleviating or mitigating the overdraft conditions that exist due to the demand of the MPWMD customers.

Methods

Determination of the amount of rainwater that can be captured via roof top collection within the MPWMD boundary (figure 4), relies on knowing the available capture (rooftop) area and hydrology for the Monterey Peninsula.

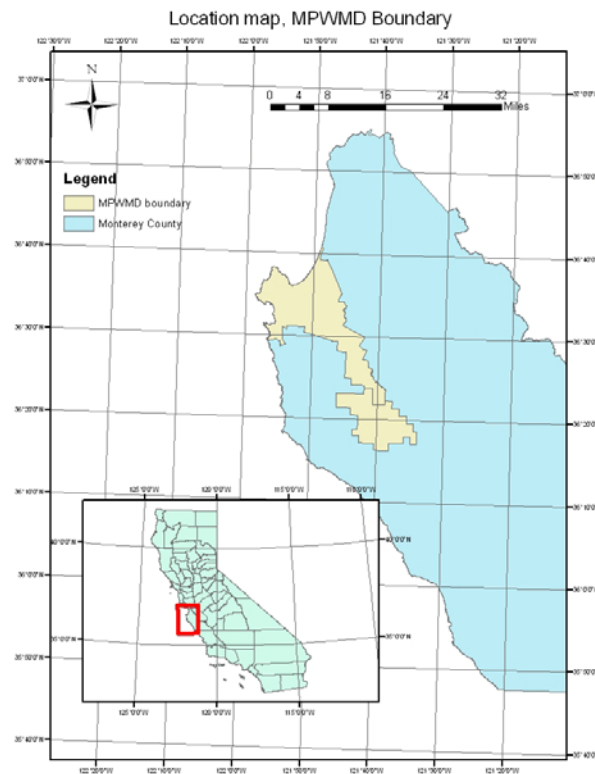
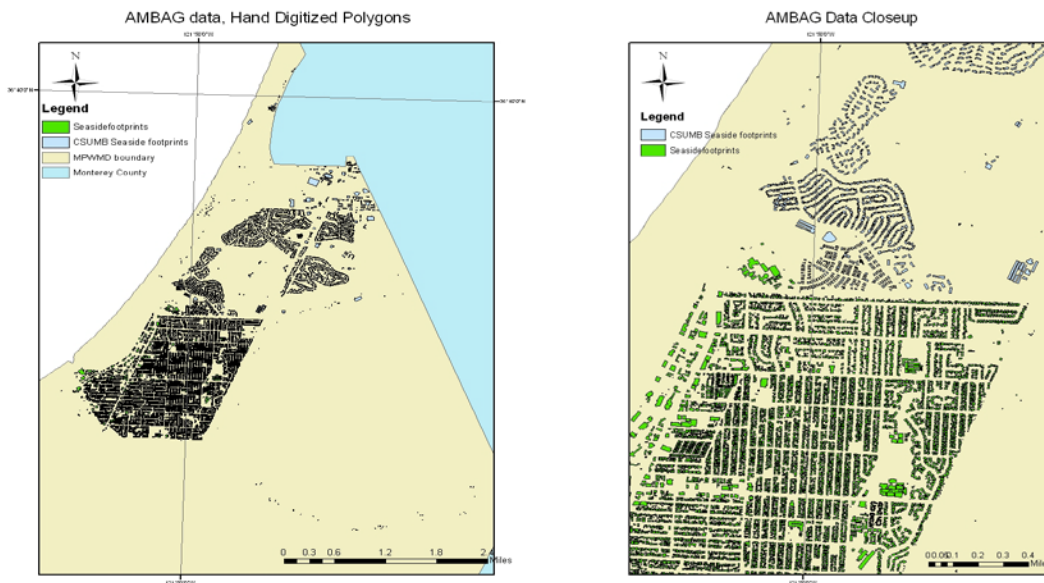


Figure 4: Location map and MPWMD boundary

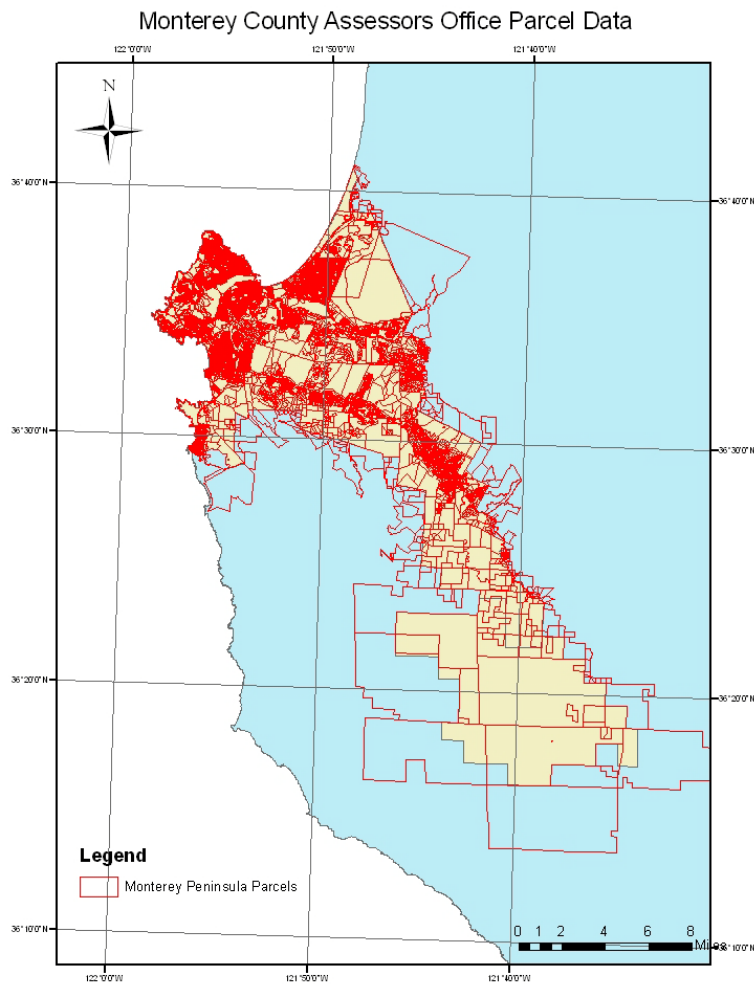
Rooftop area was compiled using GIS data available from two County agencies, the Association of Monterey Bay Area Governments (AMBAG – an entity which serves Monterey, Santa Cruz, and San Benito Counties), and the Monterey County Assessors Office. AMBAG’s data covers approximately 10% of the study area, while the Assessors Office data was used to fill in the other 90%. Although the Assessors Office data covers the entirety of the study area, it differs significantly from the AMBAG data.

AMBAG’s Marina, CSUMB, and Seaside data contains hand digitized polygons drawn over the buildings depicted on high resolution ortho photo datasets shot in 2007 (figure 5 a and b). These polygons have been drawn to match the building footprints so the area calculation is straight forward, requiring that ArcGIS “calculate geometry”. That is, utilization of software’s capacity to determine the area of each of polygon and sum them using “summary statistics”.



Figures 5 A and B: AMBAG hand digitized building footprint polygons and close-up.

Data retrieved from the Assessors office was processed in a different manner to determine the rooftop square footage. The GIS data contains the parcel property boundaries for every parcel within Monterey County (figure 6). Parcels which fall under the tax jurisdiction of Monterey County contain proxy information which was used to approximate roof square footage (approximately 80% of the parcels within the study area). Building square footage and number of stories are stored in parcel layer data tables; by dividing the square footage of the building by the number of stories a proxy for the roof square footage was derived.



The quality of this proxy was evaluated by comparing the parcel data area calculation against the actual footprint calculation for the entirety of the AMBAG data set; this comparison allowed calculation of error. The parcel area proxy calculation was then normalized by multiplying the % error * the total roof square footage determined from the Monterey parcel data (figure 7).

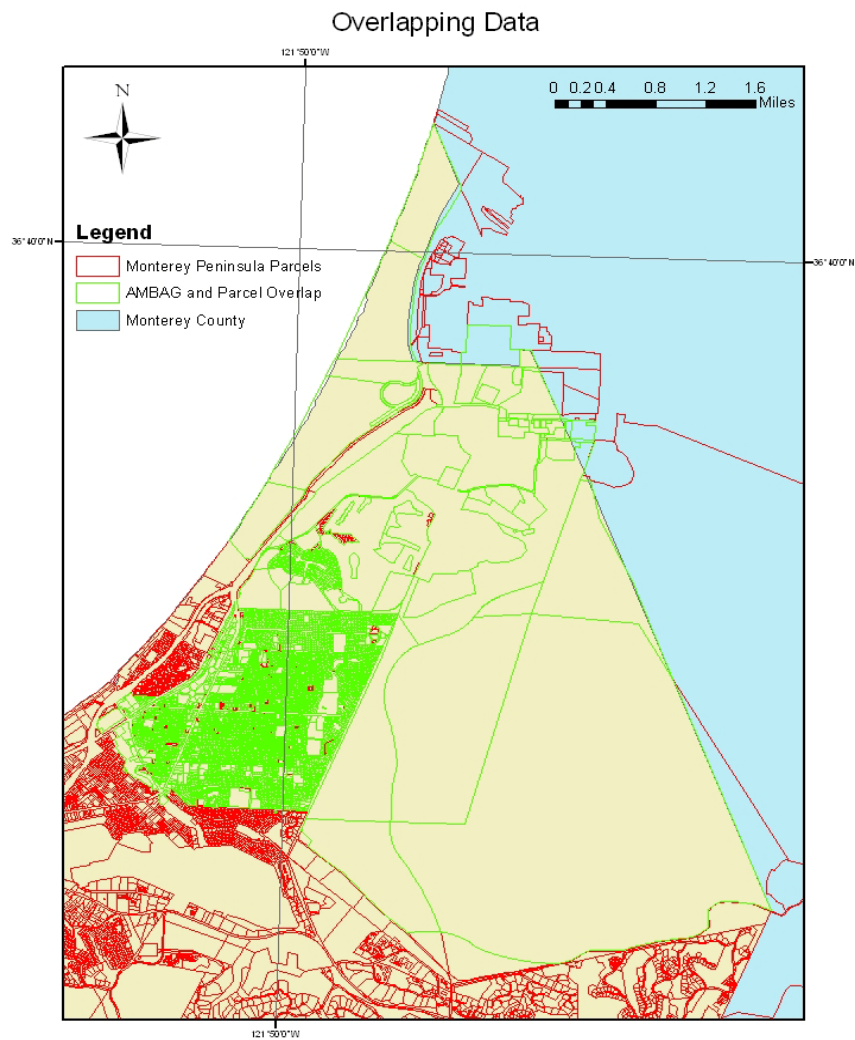


Figure 7: Data overlap between AMBAG (green parcels) and Assessors office (red parcels)

After tabulation of the total roof square footage was complete, it had to be combined with the hydrologic profile of Monterey County. Capture area * annual rainfall yields a total volume of rainwater that falls on rooftops within the MPWMD boundary.

Development of the hydrology of the MPWMD service area - average yearly precipitation, and the statistically derived 95% confidence interval, required the acquisition of a rainfall data set. A fifty eight year rain record was located. This record documents daily rainfall totals in Monterey from 1957 to present. The data set was acquired from UC Davis's IPM (Integrated Pest Management) program. The daily precipitation values were combined to generate yearly rainfall totals. This subset of data was then analyzed using a Log Pearson type III analysis spreadsheet provided by CSUMB faculty Douglas Smith, and Fred Watson. After the precipitation statistics had been generated they were combined with the roof top square footage calculation.

Results

Analysis of the parcel data set showed that roof square footage was returned for 27,412 out of the total 35,181 parcels, a 78% return rate; meaning there is more roof square footage within the study area than will be reported in this Capstone.

Total roof square footage within the MPWMD study area is determined to be 1.84 sq. miles, 1179 acres, or 51,391,667 sq. feet.

Annual rainfall within the study area is 15.9" at the 1.5 year recurrence interval – the accepted 1 year estimate derived by hydrologists (Ward 2004). Statistical analysis of the precipitation record determined that Monterey will receive between 14.6" and 17.3" of rain in an average year.

Combination of the 1179 acres of rooftop with the 15.9” rainfall average yields a total of 1563 acre-feet of water falling on rooftops within the MPWMD study area annually, (between 1434 acre-feet and 1700 acre-feet at the 95% confidence level).

Subjection of the study results to the null hypothesis criteria show that the null hypothesis must be accepted. Not enough rainwater falls on rooftops within the MPWMD boundary to offset the overdrafting of the Carmel River by Cal-Am.

Although overdrafting of the Carmel River cannot be fully mitigated by rooftop rainwater collection, a reduction of 15% of the municipal water demand is considerable. Rainwater collection is the first step in easing the Monterey Peninsula’s transition from ground water dependency, to environmentally responsible sources of fresh water.

Discussion

Harvesting rainwater in Monterey?

In evaluating the suitability of rainwater harvesting to augment Monterey Peninsula water supplies, one must consider more than the total volume of water harvestable. The value of the overdrafting offset must be ascertained via a Cost-Benefit Analysis in order to determine the real value of the water harvested.

Cost-Benefit Analysis Overview

Cost-Benefit Analysis (CBA) is a valuation tool used in the decision making process within the United States. Initially developed in conjunction with the Flood Control Act of 1936, post 1960 the Federal Office of Management and Budget (OMB) required that CBA’s be completed for proposed policies.

The OMB definition for both utilization and application of the CBA method is to “Promote the efficient resource allocation through well-informed decision making by the Federal government” (Nas 1996). Although the OMB definition defines the use of CBA within the Federal realm, the use of the CBA methodology is ubiquitous throughout local, regional, and State level decisions making processes. However, CBA has draw backs.

CBA popularity stems from the easy to follow process. The policy or program in question is analyzed to assign a dollar cost. Benefits are considered in the same way, and there after the dollar value of costs/benefits is straight forward. CBA theory states: given the benefit total is larger than the costs total the policy or program should be enacted. However, controversy arises in situations where externalities to the program exist, externality being defined as “An impact on any stakeholder not directly involved in the decision making process” (Vig 2006).

Externalities resulting from Rainwater Harvesting

Identifying and valuing externalities is a difficult and contentious task. Externalities are subjective, thus the biases of the CBA author skew the assigned values. How do you assign a dollar value to the prevention of an endangered species from losing its habitat? How do you assign a dollar value to loss of a ground water resource? When cataloging the externalities which result from collecting rainwater and using it to offset Carmel River overdrafting, the list grows very quickly.

Although positive externalities resulting from rainwater harvesting are easily identifiable, one must also consider externalities that are negative. Every gallon of rainfall which is captured and stored via rooftop collection is a gallon not being allowed

to follow its natural course. In some locations these concerns have led to policies which limit or control the amount of rainwater which can be harvested.

In Colorado where legally derived appropriative rights of large downstream users are established (i.e. California, Utah, Arizona, and Texas) the effect of rainwater harvesting has been identified as a cause for legal and political concern. “Recognizing the impact rainwater cisterns can have on streams, House Bill 1129 requires the proponents of rainwater harvesting projects to replace the water they remove from the system”(Peternel 2009). This same set of downstream considerations must be applied to rainwater harvesting on the Monterey Peninsula.

Proximity of the study area to the Pacific Ocean alleviates issues concerning appropriative water rights. Collection of rain water does not directly impact your neighbor’s ability to do so, and there are few downstream users when the ocean is between one and ten miles away (as it is throughout the study area). However indirect impacts of rainwater collection do exist - the rain water harvested is not allowed to flow to any natural or man made stormwater retention or infiltration facilities. Natural ground water recharge rates will drop as rain water is collected. The decline in the recharge rate is dependant on the volume of water removed via harvesting, geology, and geomorphology.

Porous rock formations (sandstone, old dune deposits, and decomposed granite) in gentle sloping settings allow water to infiltrate quickly. Solid crystalline rock formations in steep areas (granite, basalt, and quartzite) prevent infiltration. Discussion with MPWMD stormwater officials concluded that rainwater harvesting will have varying affects throughout the study area.

Geographically and geologically the study area is divided into two sections, land north of the Chupines fault / highway 68 and land south of the Chupines fault / highway 68. The granite geology and steep topography of the study area south of highway 68 means that minimal infiltration occurs as water flows to the Monterey Bay. Rainwater harvesting within this geological and geomorphological zone will have a negligible impact aquifer recharge rates. However, north of Highway 68 the geology and geomorphology are considerably different.

Seaside and Sand City geology and geomorphology are dominated by highly permeable sand and gently sloping old dune deposits. However Heidi Niggemeyer of the MPWMD advised me that there are no manmade storm water retention facilities due to concerns of potential ground water contamination. The Toxic Injection Control Act of 1985 does not permit the deliberate recharge of uncontaminated ground water with potentially contaminated surface waters. Only the contents of natural (or historic) water bodies Lake El Estero, Delmonte Lake, Roberts Lake, and Laguna Grande Lake, are allowed to infiltrate into groundwater. Storm water (of which the harvested rainwater is a subset) contributes minimally to the natural recharge of the Seaside Aquifer.

Beyond the environmental impacts of rainwater collection, there are human safety concerns as well. Regardless of the type of catchment surface (shingled, gravel, corrugated, etc.) particulates will be collected with harvested rainwater. To avoid clogging of cistern filters and pumps, installation of a first flush device must be installed (a valve on the roof downspout which allows the cistern owner or operator to prevent the first rain of a season from being directed into the storage tank) (Krishna 2005).

After the first flush, ongoing accumulation of particulate during the rainy season must be filtered to prevent sediment build up within the cistern. According to a local cistern owner and her installer Rain Source Water, a standard koi pond filter is satisfactory for this application (White 2009) (Arthur, 2008). Beyond particulate concerns one must take into account possible contamination which can't be removed via mechanical filtration.

Possible pathogenic contamination of the surfaces upon which rain falls has caused the EPA (both Federal and State) to classify collected rainwater as “gray water”. Gray water is not suitable for human consumption and may only be used for landscaping, gardening, car washing, and toilet flushing purposes (requiring double plumbing if the water is to be brought into a building). The captured water can be used as drinking water only after some form of tertiary treatment, either reverse osmosis or distillation (Center for Science and Environment, 2004). It is important to note that collected rainwater is an ideal source for reverse osmosis (RO) systems. Due to the softness and purity of collected rainwater, comparisons of production to waste performance of RO units are typically enhanced by 100% when compared to municipal or ocean water (Spectrapure 09).

Harvested Rainwater Value Analysis

The valuation complications described in the preceding pages mean this CBA will be extremely simplistic, only accounting for the value of the 1,434 acre-feet of water harvestable in a dry year.

Given the following constraints, this CBA better termed a value analysis won't account for the following items typical in a CBA:

- No externalities will be valued, i.e. benefits to the Carmel River ecosystem, and/or burdens applied to natural recharge of Seaside aquifer.
- Cost of maintenance will not be included (although minimal, mechanical filtration media will have to be replaced, pumps etc).
- No rebates from local municipalities for cistern installation have been tabulated.
- Huge variations in the cost of storage systems exist. Storage can be as simple as a daisy chained set of 50 gallon barrels, or as complicated as the user wishes. Cost varies depending on automation and aesthetics. A 4,000 gallon cistern can be purchased and installed above ground for \$2,000. That same volume of storage can cost upwards of \$10,000 if installed underground (Arthur, 09) (Water Tanks, 09).
- The time value of the invested capital has not been considered.

Cal-Am's current water rate structure is tiered, such that users who consume more water pay more. Table 1 summarizes the rate increases proposed by Cal-Am and approved by the Public Utilities Commission in 2008.

Table 1: 2009 Cal-Am water rates and PUC approved increases through 2011.

	Acre-foot	Average Cost per month 2008	% Increase 2008 - 2009	Average Cost per month 2009	% Increase 2009 - 2010	Average Cost per month 2010	% Increase 2010 - 2011	Average Cost per month 2011
Low Use	0.09	25.57	22	32.95	11	36.91	11	41.69
Average Use	0.12	36.67	18	44.75	10	49.92	11	56.39
High Use	0.34	141.15	44	254.25	9	280.79	11	317.24

A 4,000 gallon above ground cistern costing \$2,000 dollars is capable of containing approximately \$30 worth of water under current rates, and \$50 worth of water at the approved 2011 rate. Assuming the 2011 water rate and a fill rate of once per year, this cistern will have achieved pay back in forty years. (Note that a fill rate of once per year is an underestimate. 2000 sq feet of roof top would be capable of filling a 4,000 cistern four times during the rainy season, cutting the break even point to ten years if all the water captured was utilized). However, even this is a very conservative estimate of time to pay back considering the current CDO litigation.

Currently the draft CDO would radically modify the 2009 Cal-Am water rate structure. Rates will go from a 3 tier, to 7 tier structure (the exact consumption allowable at each tier has yet to be litigated), additionally Cal-Am will be required to reduce Carmel Aquifer pumping according to the reduction schedule in table 2 (Jackson ,08).

Table 2: Proposed CDO Carmel Aquifer pumping reduction schedule

Water Years	Max End of Year Allowable Diversions from Carmel Watershed
2007-08	10,444 acre-feet
2008-2009	9,592 acre-feet
2009-12	9,028 acre-feet
2012-15	5,642 acre-feet

It is entirely likely (yet not legally determined) that if Cal-Am is unable to meet the CDO required reductions that the purveyor will face heavy fines, the cost of which will be passed onto the customer base (Jackson, 2008). We as citizens can be assured that once the CDO goes into effect the water rates displayed in Table 1 will increase considerably (Keifor, 08). Review of Sierra Club and SWRCB briefs (official decision

has not been reached) yields a recommendation of doubled water rates. Given these increases the break even time of my hypothetical 4,000 gallon storage tank would go from forty to twenty years, (from ten to five years if all the water captured was utilized).

Conclusion, Harvesting Rainwater on the Monterey Peninsula

The citizenry of Monterey face an uncertain fresh water future. In 1995 SWRCB order WR 95-10 determined that ecological concerns for endangered species, legal conflict over public trust resources, and societal need for fresh water within Monterey had to be resolved.

In the fourteen intervening years, minor progress has been made towards mitigating the overdrafting of the Carmel River. Indeed some stakeholders theorize that the marginal gains made via the Seaside Aquifer recharge program and pilot desalination plant have been utilized to justify further growth in an already water starved community (Jackson 08).

Rainwater harvesting has been utilized for centuries to augment water supplies throughout the world. Results of this Capstone study show that the annual volume of water harvestable via rooftop collection within the MPWMD service area can replace approximately 15% of the 9,626 acre-feet of water overdrafted from the Carmel River annually. Value analysis showed that the time span of pay back on investment in a rainwater harvesting and storage system ranges 5 to 20 years.

This Capstone study may be instrumental in catalyzing the break up of gridlock between the various stakeholders involved the existing set MPWMD fresh water supply problems. Stakeholders involved in the Monterey fresh water conundrum are victims of

uninformed policy of the past. The mission statement of California State University at Monterey Bay embodies a crucial link between science and policy. My goal in completing this Capstone as a young CSUMB scientist has been to present relevant information with the hope of seeing well informed policy result.

I anticipate that this study will impact two different realms. The ethical and political landscape of Monterey ground water policy needs to be updated to reflect the precarious nature of our collective fresh water future. If we as policy makers continue to ignore environmental indicators and edicts of California State governing authorities, the citizens will pay fines for delaying actions long over due.

Rainwater collection enacts a positive benefit on the environment, while buffering against the impacts of future water rate hikes. Empowering everyday citizens to become a part of the green movement will have positive societal implications.

Monterey is in desperate need of an environmentally responsible source of fresh water. Rainwater collection is not capable of fully meeting Monterey Peninsula's fresh water need, but is it reasonable to expect it would? There will be no quick fix solution to Carmel River overdrafting. Reductions in pumping will only be met through a patchwork of efforts, of which rainwater collection will be just one. Thorough evaluation of the potential to harvest rainwater will be an important step towards making the municipalities of the Monterey Peninsula a sustainable part of our global community.

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