Evaluation of Urban Water Sustainability

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1. Introduction

Water has long been an issue in the American west. In Southern California one need only go back to Mulholland's siphoning of the Owens Valley water resources to understand the overreaching uncertainty faced by the public servants of such growing cities[1]. However, once water contamination was found to be a major threat to urban populations, water distribution has focused on accessibility over conservation (See Melosi, 2000). Implicit in this reasoning is that water must be kept affordable and readily available. However, this has proved difficult as there has been a persistent decline in available water resources as the population in the American Southwest has boomed.

California water demand continues to exceed local water supplies, an issue exacerbated by continued population growth and drier conditions (less precipitation, hotter temperatures, and higher rates of evaporation). The current drought in California has brought attention to aggregate consumption levels within the state and the larger Southwest region. Extensive interregional water conveyance projects are currently used in order to supplement local water resources. However, this vast distribution network has had a negative impact on the natural habitats found within the water's source. In an effort to restore the health of our natural water systems, protect the economy, reduce energy consumption related to water relocation, and maintain a high standard of living, Senate Bill No. X7-7 (Water Conservation Bill of 2009) was passed by California Governor Schwarzenegger. This bill requires all urban water per capita use to decrease 20 percent by December 31st, 2020. This water conservation act has prompted the expansion of efficient water management practices at the state, regional and local levels

Historical Overview

The water authority for cities and regions can be subject to a complicated web of municipalities, districts, private owners, and watershed authorities. Particularly in California, watershed authorities have been an increasing trend for areas over the past 40 years. The regions incorporated into the City of Riverside and the City of Irvine are located within the Santa Ana Watershed. Thus, both cities are under jurisdiction of the Santa Ana Watershed Project Authority (SAWPA). SAWPA was established in the seventies to mitigate water resource management issues between cities and agencies that lie within the Santa Ana Watershed area. (1) The watershed regional authorities have become a popular way to organize water resources. The benefits of organizing water distribution and use by watersheds is that the water can be managed from the source through treatment, distribution, and discharge. Any contamination can be controlled without significant political or bureaucratic delay. Also, due to the criteria of the group of groundwater legislation, known as the Sustainable Groundwater Management Act, enacted in

[1] For an excellent exposition, see Reisner (1986).

2014, areas that are grouped into watersheds can more easily deal with the groundwater issues locally. (2)

Working within watersheds, however, can also further complicate water projects. Due to county boundaries and historic city limits, certain areas are split between requirements and funding for the governing water district and the watershed. The City of Palmdale is located within the Antelope Valley watershed. However, since a majority of the area is incorporated into Los Angeles County, the city has unique challenges in dedicating funding for watershed projects. The Antelope Valley Integrated Regional Water Management (IRWM) group is the governing authority; however, the group is not as well established as SAWPA and therefore, does not have the same authoritative presence as SAWPA. Despite this issue, the City of Palmdale has been active in generating policies for the IRWM in the Antelope Valley through systems and policies that promote conservation in irrigation, which accounts for the majority of the city's water use. (3)

The Riverside Green Action Plan (RGAP) is an example of water conservation proposed by a Southern California city. The plan was created as part of a larger effort by the city of Riverside to shed its image as regional agricultural outpost and reimage itself as a modern urban center. From 2000 until the financial crisis of 2008 Riverside grew at annual rate between 3% and 5%, which exceeded both the state and national population growth rates. Such a transition requires a balancing act between respecting the city's history and modernizing its policy apparatus, in particular, with respect to water policy. The median household income in the city of Riverside is nearly 11% below that of the state. Secondly, home values in Riverside are lower than communities that are closer to downtown Los Angeles and to the beach cities. This has made Riverside a prime location for lower middle class families looking to purchase homes.

The purpose of this paper is to compare water conservation efforts between three Southern California urban centers: Riverside, Irvine and Palmdale. The city of Irvine is often regarded as the model for modern water policy and their experience in developing household water budgets is used as an example for water policy discussions around the country. Irvine is similar to Riverside in a variety of ways. Each roughly equidistant from downtown Los Angeles, they are both home to major research universities (UC Irvine and UC Riverside, respectively) and are connected to downtown LA via the Metrolink train line. However, as Riverside has a long history as an agricultural center of Southern California, Irvine is a new, planned community, which was incorporated only in 1971 by a land grant from the Irvine family. The city's median household income is over 65% higher than the state and nearly 85% higher than that of Riverside. And perhaps most importantly, Irvine was not bound by old municipal infrastructure. As Melosi (2000) points out, given the size and resources involved in municipal water systems, in particular bad systems, a city is bound to them for a long period of time. However, Irvine had 150 years of water system building experience to draw upon before implementing their infrastructure. Clearly, given that Irvine had the financial resources, the political will and the lack of historical baggage; it is no surprise that they became pioneers in water distribution policy. Palmdale, on the other hand, bears a larger resemblance to Riverside in income demographics, its median household income nearly 20% below that of the state. Just over 60 miles from downtown Los Angeles, Riverside is also connected through a commuter train line and has recently become part of the periphery of the Los Angeles Metropolitan area.

In light of the population growth, economic challenges, extreme drought, and environmental burden of water relocation in California, we have chosen seven indicators for water management and propose an index by which water utilities can evaluate their progress toward water conservation in this report. Lastly, we offer several recommendations to Southern California cities to aid in their water conservation and sustainability efforts.

2. Methodology

In this section, an overview of the seven indicators selected for this evaluation are presented. Using both quantitative and qualitative measures, these seven indicators are: (1) *Water Quality*, (2) *Recycled Water,* (3) *Pricing Models*, (4) *Environmental Protection*, (5) *Rebates*, (6) *Landscaping*, and (7) *Education*.

In order to quantify the qualitative data used in our analysis, this paper uses a Borda count method to verify whether each city exceeds, meets , or fails to meet the threshold defined by each indicator. Borda counts are a standard tool in voting theory to choose winners among voters who rank candidates in order of preference. For each indicator, each city is given a value of 1 for each indicator that exceeds the threshold value, 0 for meeting the threshold value and -1 for failing to meet it. In the case where the variable is dichotomous, such as whether a policy was implemented or not, then values are limited to 1 and -1. Summing over all indicators per city allows for scalar comparisons of all three cities. The city with the highest number is the strongest in meeting or exceeding the indicator threshold values given the indicators chosen.

One concern with this method is that it weights each indicator equally. It would be straightforward to weight according to a variety of preferences. However, each set of weights will reveal the bias of the researcher.

2.1 Water Quality

Water is the basis of all life and the quality of water impacts the quality of life for humans, wildlife and ecosystems. The ever increasing population size poses a big challenge on the supply of safe and reliable drinking water, and the excessive amount of wastewater generated by communities has altered many natural habitats. Ecosystem protection and water quality are important components of water conservation and together they describe the concept of water sustainability. The evaluation of water quality not only concerns drinking water quality, but also encompasses groundwater and wastewater management. Several parameters including drinking water testing, violations received in last ten years, groundwater contamination, wastewater management and sanitary sewer overflow (SSO) preventions are considered for evaluation in this section.

2.2 Recycled Water

Recycled water (RW) is an important component in sustainable water practices. As communities continue to grow the demand for water also increases, and although there are many tools and practices available to conserve water, this alone will not be enough to sustain the growing population's water needs. RW is a way for a community to increase its water budget and decrease its water importation.

Four indicators will be used to measure how well RW is being utilized by each of the three water districts in this case study. The first indicator is evaluating the ability of a water district to produce RW; this includes such factors as obtaining a permit from the state water board and regional water district, and having a facility capable of processing the wastewater (WW) to the required standards set forth by the state. One of the major limiting factors of a city's potential RW use is the amount of WW available to recycle; hence, the second indicator is the volume of RW produced compared to the volume of WW collected.

How the RW is currently being allocated also needs to be considered. It is important that the usage is providing both the largest revenue to the utility to cover the expense of production, and that the usage is meeting the most urgent environmental needs of the region. Therefore, effective RW use is the third indicator. Lastly, the fourth indicator will evaluate the water utility's plans for implementation or expansion of RW usage, and will include criteria such as financial feasibility, developed and approved plans, and delivery feasibility.

2.3 Environmental Protection

In environmental protection, the protection of surface waters can make a significant impact on the quality of drinking water, which can be accomplished through stormwater pollution constituent management. Stormwater technologies include a growing trend of Low Impact Development (LID) methods but the method is relatively novel. Therefore, when assessing a city's regulations and implementations of LID methods, requirements for new developments, contribution to the growing knowledge base of the technologies and the potential implementation benefits will be analyzed.

2.4 Pricing Models

There are two features that are evaluated with regards to urban pricing models in this report. The first is whether the city uses increasing block rate pricing. The second focuses on the use of water budget rates, which adapts in the increasing tiered rates to take into account specific household characteristics.

2.5 Rebates

Rebates are a tool commonly used by water suppliers to encourage upgrades to more efficient appliances and devices used by home owners, commercial, and industrial sectors. The consequent upgrades performed by targeted users should result in lower water or energy consumption, and reduce operating costs for the supplier. The rebate systems used by IRWD, PWD, and RPU are evaluated by comparing their qualitative effectiveness based on the availability of the rebates, their diversity, and their possible effectiveness in reducing water usage. The availability of rebates is measured by the number or monetary value of available rebates per customer, and also by the number of choices available to the customer. The diversity of rebates is evaluated by looking at the total number of available rebates, and the target audience (commercial and industrial vs. homeowners). Finally, the water saving capability of the rebates are assessed on their engineered efficiency. Although predicting the amount of water that will be saved in each city via rebates is outside the scope of this paper, we qualitatively assess water saving potential using engineered efficiency as a quantitative tool.

2.6 Landscaping

Landscaping is an important aspect of water conservation that can greatly dictate total water consumption. In the arid region that RPU, PWD, and IRWD are located, many homeowners still prefer traditional Bermuda or Fescue turf landscapes because of the aesthetic appeal. However, while the appearance is pleasant, both of these grasses require a substantial amount of water for irrigation. Three key areas are considered to assess the measures in place for each city to reduce their water usage related to landscaping: revision of mandates, access to information, and homeowner feasibility. Revising mandates consider the political and legal aspects such as zoning and applications. Easy access to useful "how to" information ensures homeowners are properly educated while rebate programs address homeowner feasibility and whether or not the transition is the best action for them to undergo. Therefore, the type of landscape and the implementation measures are important considerations for a city to reduce its future water consumption for irrigation.

2.7 Education

While developing more sustainable water technologies and policy is important, solely providing them to the general population will not result in significant change if these technologies remain underutilized. Previous research shows that environmental education successfully initiates behavioral change when it embeds the student’s learning in real-world contexts [7DH] that emphasize the connections between others in their social circles, providing students with a sense of competence [8DH]. Due to programs emphasizing people as an integrated part of the water ecosystem motivating higher rates of environmental attitudes, comprehensive water education programs should involve an integrated curriculum stressing human impact on water sources [9DH]. Behavioral change resulting from education programs is difficult to measure, and no city discussed in this paper has been able to quantitatively assess them. Thus, this paper evaluates the effectiveness of a city's education programs by measuring whether a city is effectively reaching different populations, offering a variety of comprehensive programs, and employing effective learning methods.

3. Discussion

3.1 Water Quality

3.1.1. Drinking Water

Drinking water, groundwater and wastewater quality were evaluated for the three cities; Irvine, Palmdale, and Riverside. Drinking Water quality is regulated and monitored by the California Department of Public Health (CDPH). Currently, there are 93 primary contaminants and 16 secondary contaminants that are regulated. Notification levels are also suggested by EPA for 30 unregulated contaminants, which are pending regulatory legislation[2]. Quarterly water quality reports need to be submitted to the EPA by the CDPH through the Safe Drinking Water Information System (SDWIS/FED), which includes "public water system inventory information, incidents of violations for maximum contaminant levels (MCLs), maximum residual disinfectant levels (MRDLs), monitoring and reporting (M/R), and information on enforcement activity related to these violations[3]".

The goal of all water utilities is to provide safe and clean drinking water to their consumers. All three cities have devoted their resources to provide great quality water. However, IRWD and RPU are larger facilities and more funded than PWD, and are able to conduct more rigorous testing to comply with regulations. IRWD provides water to the city of Irvine and some surrounding areas. IRWD's water supply meets and/or exceeds all quality standards set forth by both the state and federal governments. Water samples are taken from over 99 sample points throughout the district and more than 20,000 samples are processed by state-certified laboratory. All three water utilities also process some tests for unregulated contaminants, which are pending regulatory legislation by the EPA, such as hexavalent chromium and vanadium[4], [5], [6]. Monitoring unregulated contaminants helps the EPA to determine the geographical presence of various contaminants.

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[2] "Drinking Water Contaminants". May, 2009. USEPA. http://water.epa.gov/drink/contaminants/
[3] "Annual Compliance Report". 2011. California Department of Public Health.
[4] 2014 Water Quality Report. Irvine Ranch Water District. 2014. http://www.irwd.com/images/pdf/water-sewer/IRWD2014WQR.pdf
[5] 2013 Consumer Confidence Report. Palmdale Water District. 2013. http://www.palmdalewater.org/about/reportsstudies/water-quality-reports
[6] Water Quality Report 2013. Riverside Public Utilities. 2013. http://www.riversideca.gov/utilities/pdf/2014/2013-Riverside-Public-Utilities-Water-Qualtiy-Annual-Report.pdf

RPU also collects more than 20,000 water samples each year that are analyzed by state certified independent laboratories. More than 200 possible contaminants were screened. According to SDWIS database, no drinking water violations have been reported for the last 10 years.

Drinking water samples in PWD are processed by an in-house state certified laboratory. They test for pH, hardness, coliform, TOC and UV absorbency. Other required regulatory compliance samples are sent to contracted laboratories for analysis. PWD plans to build a larger state-of-art laboratory in order to perform more analysis in-house. PWD has met all regulatory compliance since 2008. Three violations were received between 2003 and 2007 including exceeding the MCL of TTHM and Dichloromethane. Since 2008, PWD upgraded their water treatment technology and started utilizing granular activated carbon to remove organic contaminants in the drinking water.

2004~2009	City of Irvine	City of Riverside	City of Palmdale	
	IRWD	RPU	Palmdale Water District	National Average
Laboratory	In House	Contracted	Patial In House	
Exceed Health Guidelines	16 chemicals	15 chemicals	15 chemicals	4
Health Standard Exceedences	1 (Manganese)	1 chemicals (Alpha particle activity)	1 chemicals (manganese)	0.5
Pollutants Found	29 chemicals	30 chemicals	29 chemicals	8
Contaminants Not Detected	185	212	128	N/A
Tests Conducted	25911	21838	9038	420
Meet regulaory compliance	No violations were reported for this system since 2004	No drinking water violation has been reported since 2004	3 violations received between 2003 and 2007 (TTHM, Dichloromethane)	

Figure X. Comparison of drinking water quality between the cities. Data are obtained from National Drinking Water Database.

3.1.2 Groundwater

Drinking water quality is often affected by groundwater quality, especially if a city relies heavily on groundwater resources. Generally, agricultural and urban activities as well as leaching of geological constituents affect groundwater quality. Utilities are encouraged by the state to utilize local ground water to help reduce the burden of importing water. The Irvine sub-basin is part of a larger basin called the Coastal Santa Ana Basin. Approximately forty-eight percent of IRWD's water supply comes from local groundwater wells and IRWD operates 25 groundwater wells. Areas in the Coastal Basin, from which IRWD's groundwater is supplied, have a total dissolved solids concentration from 250 to 25,000 mg/L. Groundwater in Irvine contains levels over 1,000 mg/L of dissolved solids due to coastal seawater intrusion and artificial recharge of groundwater with treated wastewater, imported water, and water from the Santa Ana River. Stream flow of the Santa Ana River is affected by increases in population and urban development, resulting in greater discharges of treated wastewater into the river. Consequently, groundwater quality is influenced by the chemical characteristics of the artificially recharged water.

Nitrates and pesticides are common contaminants that occur in groundwater as a result of agricultural practices such as vineyards, livestock holdings, and cropland. The Orange County Water District reported levels of nitrates from 1 to 7 mg/L, which is within the federal standard of 10 mg/L. As for pesticides, only trace amounts were detected in fifty-six percent of wells tested. There are some historically marshy regions within the Coastal Basin that contain levels of arsenic and uranium above the EPA regulations of 10 µg/L and 30 µg/L, respectively. High concentrations of these elements can result from naturally occurring geochemical conditions and evaporation. Within the basin, average levels of arsenic and uranium are 1.4 and 4.4 ug/L, respectively. The IRWD water quality report of 2014 indicated no outstanding levels of regulated contaminants, however, groundwater quality assessments showed that vulnerability to contamination from certain industries was location-dependent. For example, the groundwater pumped from the Dyer Road Wellfield (West Irvine) is most susceptible to contamination from gas stations and metal plating industries.

Palmdale is part of the Antelope Valley Groundwater Basin. Forty-three percent of the source water in Palmdale comes from groundwater and the remaining from surface water from both the State Water Project and a reservoir created by the Littlerock Dam. Recharge to this basin is derived from perennial runoff from surrounding mountains through percolation. Minor sources of recharge are from irrigation water and septic tank effluent. However, groundwater levels have declined from increased pumping due to population growth and climate change. Land use in Palmdale is varied among residential, industrial and commercial, but it, most notably, contains an air force base (Edwards AFB). The presence of the base has played a significant role in groundwater contamination in the region. Trichloroethylene (TCE) is used an industrial solvent to clean metal parts and has been found in groundwater wells near the base. It is regarded as a carcinogen associated with several types of cancers such as liver and cervix cancer. The US EPA regulates this contaminant at 5 µg/L. A report from the California Environmental Protection Agency reported levels up to 302 µg/L. As of 2008, a groundwater containment system has been implemented in this region to remediate the water and soil before it can reach public access. Recent consumer confidence reports on water quality show that there are no outstanding levels of contaminants in PWD's drinking water.

The majority of RPU's water supply is from local groundwater. Geographically, there are issues of perchlorate contamination by the Rialto plume about 25 miles northeast of the University of California, Riverside. There is also a perchlorate and TCE plume in the west Riverside area associated with Norton Air Force base and Lockheed Martin. In the city of Riverside, there are high concentrations of total dissolved solids (TDS) and nitrate concentrations that are most commonly associated with agricultural activity. Overall, the city of Riverside experiences challenging issues with groundwater contamination due to a high number of contaminants such as arsenic, hexavalent chromium and perchlorate. The highest concentration detected for arsenic was 60 ppb, which has an MCL of 10 ppb. The US EPA has decided to regulate perchlorate under the SWDA, but a decision for its maximum contaminant level is under development. The CDPH has regulated perchlorate at 6 μg/L since 2007 due to its affects on public health.

3.1.3 Wastewater

Wastewater treatment and discharge are also important parameters for evaluating the water quality of a utility and its impact on the ecosystem. Wastewater discharge standards are regulated by the State Water Resources Control Board (SWRCB). Sanitary sewer overflows (SSOs), which result from broken pipes, may discharge untreated sewage directly into sources of water such as lakes and rivers. Preventing SSOs prevents the contamination of drinking water sources.

IRWD has a very comprehensive Sewer System Management Plan that consists of four major parts: 1) comply to? the state's regulation, 2) prevent sanitary sewer overflow (SSO), 3) assign responsibility to program stuffs and executors, 4) plan for cleaning sewer system, emergency and replacement plan. The SSO database showed that there were 3 SSO incidents in 2013, and zero incidents in 2014, indicating the Irvine has improved their efforts on implementing SSO management plan and preventing any further occurrence of SSOs. The city's business WW source control program and pharmaceutical disposal program also help minimize the amount of toxic substances discharged into the WW, particularly by preventing the disposal of unused or expired prescriptions down the toilet or sink. Orange County Sanitation District (OCSD) also has an ocean monitoring program which oversees the quality of water and marine life.

Riverside Water Quality Control Plant (RWQCP) provides tertiary treatment for 40 million gallons of wastewater per day. The final water product is dechlorinated and then discharged into Santa Ana River. RPU has developed an industrial waste program to improve wastewater quality. This program requires businesses such as restaurants, auto shops, and dry cleaners to obtain yearly permits in order to protect the sewage treatment plant. RPU also has a Sewer System Management Plant to comply with AWRCB's regulation. The goal of the plan is to reduce SSO, improve the collection systems, and raise public awareness about SSO related issues. There were a total of eight SSO incidents reported in 2013 and seven incidents reported in the first half of 2014. The frequent occurrence of SSOs in Riverside is attributed to the older pipe systems that are under great stress due to the rapid population growth.

WW collection and treatment in Palmdale is managed by the Sanitation Districts of Los Angeles County (LACSD). Part of the effluent from LACSD is treated by Palmdale's water reclamation plant and then used to recharge the Antelope Valley Groundwater Basin. The remaining effluent is disposed via crop irrigation and surface spreading. LACSD is currently upgrading the Palmdale WWTP with tertiary treatment facilities, seasonal storage and reservoirs in order to dispose all effluent at agronomic rates and terminate land application. No SSOs were reported in 2013, however one SSO has been reported for 2014.

City of Irvine	City of Riverside	City of Palmdale
Irvine Ranch Water District	Riverside Public Utility	Palmdale Water District
(1) Business wastewater source control program (2) Ocean monitoring program	Industrial Waste Program	N/A
0 SSO reported in 2014	7 SSOs reported in the first half 2014	1 SSO reported in 2014

All three cities are in compliance with drinking water regulations. There are no regulated contaminants present that exceed their MCLs, thus Irvine, Riverside and Palmdale receive a (0) in terms of meeting regulatory compliance. Having resources devoted to quality control is another important parameter in assessing drinking water quality. Irvine and Riverside, being larger public utilities, are able to dedicate more resources to conducting and monitoring drinking water quality with more sampling and tests than Palmdale. For this parameter, Irvine, Riverside and Palmdale receive a (+1), (+1) and (0), respectively. With respect to groundwater quality, Irvine and Palmdale receive a (0) as they do not have elevated levels of contaminants in their groundwater, whereas Riverside receives a (-1) due to its relatively high levels of perchlorate and hexavalent chromium in its groundwater. Finally, Irvine and Palmdale receive a (0) for their ability to reduce and prevent SSO, and Riverside receives a (-1) in this category for its high number of SSOs in the past two years. However, Riverside and Irvine receive a (+1) for having programs that increase wastewater quality for businesses. Palmdale does not have any of these programs, but does impose some regulations, thus it receives a (0).

3.2. Recycled Water

The California Water Code describes RW as "... water which, as result of treatment of waste, is suitable for direct beneficial use or a controlled use that would not otherwise occur and is therefore considered a valuable resource." In other words, RW is WW that has been highly treated so that it is safe and suitable to be reused for agricultural and landscape irrigation, industrial processes, replenishing of groundwater basins, and other applications.

There are three different levels of RW; secondary treated disinfected RW, tertiary treated RW and advanced treated RW. To reduce the risk of adverse outcomes such as infection, the state regulates how each category of recycled water can be used based on the level of treatment. Secondary treated disinfected RW is used for non-food crop irrigation and for restricted urban and recreational uses. Tertiary treated RW requires filtration and is safe for agriculture and food crop irrigation, and unrestricted urban and recreational use. The standards for tertiary treated RW are near those of drinking water standards, it cannot exceed 2.2 MPN coliform per 100 milliliters, whereas drinking water must have less than 1 MPN per 100mL. Advanced treated recycled water utilizes advanced filtration, called reverse osmosis (RO), to produce water that is more pure than tap water, and can be safely used for any application including drinking water augmentation and groundwater recharge. RO is the only method that is capable of removing all substances such as pharmaceuticals, pesticides, and heavy metals. Thus, for secondary and tertiary treated RW the chemical quality must be taken into account by municipalities for proper application. Many municipalities are in the process of adapting the use of either tertiary or advanced tertiary RW, which is a cost effective alternative to desalination. Implementation of RW for groundwater recharge and landscape irrigation, rather than direct augmentation, may be a wise starting point, especially where there is resistance to embrace RW due to the "yuck factor." This is one reason it is critical for water utilities and educational institutions to educate the public about water scarcity and the valuable resource that RW is.

Recycled water is delivered only through 'purple pipe' plumbing. This distribution system is required by law to be completely separate from the drinking water infrastructure. This poses one of the largest financial burdens to a water utility. For example, the estimated cost to retrofit purple pipe into the infrastructure to reach the majority of RPU users would be over half a billion dollars. Instead, RPU has a two-phase strategy to minimize cost and maximize RW implementation. In the first phase they will update facilities and expand the existing purple pipeline by six miles, which will deliver 5,000 AFY for groundwater recharge, 2,600 AFY for wholesale to WMWD, and 1,000 AFY to customers for irrigation (4). Wholesale is the sale of water to other water utilities, and can be a very cost effective strategy to generate revenue, as delivery is to one location instead of throughout a service area. As of 2010, RPU collects approximately 38,100 AFY of WW and produces approximately 35,000 AFY tertiary treated RW. However, only 260 AFY is actually utilized, the remainder is discharged into the Santa Ana River (SAR). It is important to note that RPU is required to discharge a minimum 25,000 AFY into the SAR to maintain downstream flow to Orange County. Thus, RPU's usage was calculated from the eligible 10,000 AF/yr. RPU began updates to their WWTP facility in 2012, construction is scheduled to be completed by the end of 2015 and the plant will be able to produce up to 40,000 AF/yr of RW (5). Phase two is more costly and consists of laying an additional pipeline to another area for groundwater recharge; however, this construction will not begin until phase one is completed. The estimated cost for both phases is 155 million, and will only raise customer's bills a total of 9 dollars a month (gradual increases over several years) (6).

LACSD collects and treats WW for Palmdale and the Antelope Valley service area. Palmdale generates approximately14,000 AFY of WW. However, the WWTP facility is not equipped to treat to RW standards. Currently, they discharge their WW as secondary effluent, the minimum requirement by the state for WW discharge. PWD has obtained a RW permit, completed engineering plans for updating the WWTP, and acquire approved these plans, and are currently working on their budget to begin implementation. (How do they plan to utilize RW?)

IRWD does not face the same dilemma of retrofitting purple pipe as most cities do. Irvine, the founder of the purple pipe, laid purple pipe at the same time the original infrastructure was being built, and the city continues to do so for all new construction. This infrastructure allows IRWD to deliver advanced treated RW to commercial buildings, apartment complexes, and gyms for toilets and urinals, and other applicable applications of RW. IRWD is Orange County's largest retail water district, providing water to over six cities. In fact, IRWD owns and operates the most robust RW system in the USA, with 400 miles of purple pipe, 12 storage reservoirs, and almost 5,000 metered RW connections. IRWD recently expanded their Michelson Water Recycling Plant facility from producing 20,000 AF/yr to 32,000 AF/yr. They also own the Los Alisos Plant, which produces 7841 AF/yr. Twenty one percent of IRWD's water budget is supplied by RW.

Add the water portfolios for each city current and future plans.

Each of these three cities offers a unique set of circumstances which greatly influence their current and future use of RW.

3.3. Environmental Protection

Low-Impact Development (LID) is a growing trend among development efforts around the world that replaces traditional stormwater infrastructure.[1WW] By developing an area, the permeability of the land to allow water to infiltrate decreases significantly. The result is an increase in stormwater runoff which can cause damaging flood conditions. The areas developed are generally high in population traffic and vehicular density, which contribute to high amounts of pollution. Typically, runoff in developed areas will transport the pollution to surface water and groundwater sources. Referred to as *Non-Point Sources*, the run-off pollution is not regulated due to the logistical complications of testing and treatment. Unless properly managed, stormwater runoff can cause severe damage to property, human life, and the environment both physically and through chemical contamination.

Current development processes manage the stormwater runoff through a series of best manageable practices (BMPs) designed to collect and release the water at a controlled rate. LID practices are attempting to develop BMPs that are capable of mimicking the predeveloped hydrologic conditions so that the stormwater runoff can be collected and used to recharge aquifers or for irrigation. However, research is largely inconclusive regarding the LID BMPs and the knowledge base is largely anecdotal. Thus, many municipalities are apprehensive to create specifications that require LID BMPs for developments despite the possible benefits of the new technology. The analysis of a city will, therefore, also include whether a city is contributing to the growing knowledge base through water quality testing or publishing case studies.

A development governing organization will have developers and planners submit a Water Quality Management Plan (WQMP), which will detail the drainage and treatment facilities for a development. If a city has developed requirements within the WQMP, they will meet the requirement for regulatory efforts. Finally, the potential benefit to a city through implementation of LID is limited by the geographic and geologic characteristics. LID BMPs are most useful in order to recreate the natural hydrologic conditions before development. The quality of the soil can severely limit the application of LIDs by limiting the infiltration capacity. The soil quality is described by the USGS (United States Geological Survey) as a grade ranging from A to D. The grading refers to the ability of water to travel through the soil. Highly porous soils, such as sand, would receive an A, whereas poorly draining soil, such as clays, would receive a D. By implementing LID BMPs in areas with high infiltration capacity, the soil will provide natural drainage which will increase the effectiveness of the LID BMPs. In areas with poor drainage, the use of LID BMPs would not be advised since they cannot be effectively implemented.

The City of Riverside and Riverside County initiated efforts to utilize LID BMPs to develop more environmentally sound expansion practices for their community. Through the GAP (Goal 16.h), the City of Riverside plans to *develop easy to understand forms and handout literature that will enable designers and contractors to implement the water efficiency standards of the Green Building Code on their projects in Riverside and streamline the design and plan review process*. LID BMPs are an important aspect of the plan to increase water efficiency standards.[2WW] The City of Riverside and the Riverside County Flood Control and Water Conservation District (RCFCWCD) have worked to develop specifications and worksheets to provide contractors and developers implement LID on work sites. The handout literature expedites the design process and allows simple assimilation into any site development plans and worksheets simplify the verification and design of the LID BMPs.

Hydrologic Soil Characterization in Riverside, CA	
A	35.30%
B	14.50%
C	22.30%
D	19.50%
Undefined	8.40%

The Santa Ana Watershed Project Authority (SAWPA) has also contributed design considerations to help coordinate development within their watershed, which also includes Irvine, CA. The soil quality for the City of Riverside has a high infiltration capacity which is described in Table _, and a high potential benefit of implementing the LID BMPS. However, due to the lack of specific regulation, Riverside has still not met all considerations for LID BMP stormwater runoff development but has demonstrated creative projects to promote LID technology.

Despite the lack of research and cost benefit analyses available to support the implementation of the LID BMPs, the RCFCWCD engineered and designed a retrofit of their current building to demonstrate the LID BMPs. The building has multiple different LID BMPs including porous concrete, porous asphalt, bioretention ponds, planter boxes, and permeable paver walkways. By also monitoring the water quality through an on-site testing station, the RCFCWCD can quantitatively express the effectiveness of the LID BMPs. Another benefit of demonstrating the LIDs is that the site expresses the aesthetic benefit of using LIDs offering intricate landscaping and drought tolerant plants. The results of the LID BMP monitoring system will be submitted to the California Stormwater Quality Association (CASQA) and the ASCE International Stormwater BMP database. Both organizations collect data regarding LID BMPs from various different regions and climates to understand the functions and applications of the relatively poorly understood novel technologies. The distribution of the information collected in Riverside will be used to design sustainable development practices throughout the United States and the world.

The City of Irvine is incorporated into Orange County and falls under the jurisdiction of the OC Public Works department. Since the region falls within the vicinity of the Santa Ana watershed, the area is also under the jurisdiction Santa Ana Regional Water Quality Control Board and SAWPA. Therefore, development projects in the City of Irvine are subject to permit applications and restrictions. In response to the permitting, Orange County Public Works has developed a series of plans and guidelines to develop areas. Depending on the size of the development project, the project will be determined as a *Priority Project* or *Non-Priority Project*.[3WW] If a development project is classified as a *Priority Project,* a WQMP is required which involves a thorough analysis of the implementation of LID BMPs for the site. The final plan submittal must be approved by the OC Planning department.[4WW] To assist in the design and development of the WQMP, the OC Public Works department has compiled a technical data sheet for LID BMPs.[5WW] Orange County commissioned a study by Orange County Coast Keeper's that investigated the potential use of LID BMP's, published the results, and since has been referenced in the development of other cities' policy statements.[6WW] The soil characteristics in Irvine do not have high infiltration capacities since more than 80.7% of the soils are classified by a C or lower according to Figure _ , therefore the potential application has been fully met for Irvine, CA .

Hydrologic Soil Characterization in Irvine, CA	
A	10.40%
B	18.80%
C	36.50%
D	30.70%
Undefined	3.50%

The City of Palmdale is incorporated into the Los Angeles County area however, due to the geographical constraints; Palmdale is exempt from many county regulations and requirements. Palmdale also does not share the same watershed that LA County does (LA River Watershed) rather it falls within the Antelope Valley Watershed (AVW). The AVW does not naturally drain into the Pacific Ocean. Due to the discrepancy of the watershed authorities, the City of Palmdale is exempt from the statutes and requirements in LA County. The MS4 stormwater discharge permit that LA County submitted for the incorporated area includes certain exclusions for the cities of Lancaster and Palmdale. Therefore, the stormwater management requirements for the city are under the control of the city itself. Currently, the city does not have any requirements for water quality management plans or LID BMPs. The only development requirement for the area is to adhere to the Master Plan of Drainage.[7WW] Due to the lack of support for LID investment, the City of Palmdale does not have any projects investigating the implementation for LIDs. However, current plans for LID are in development and have referenced Orange County's efforts.[8WW] The unique hydrologic properties for the area are very important since the area does not drain to the ocean. Therefore, the potential reuse is very high. The soil conditions are highly favorable for infiltration due to high soil qualities (over >70% over a grade of B) as referenced in the Table above. Since the city does not have any incentives for LIDs and high geological benefit potential for implementation, the city does not meet the criteria for the indicator.

Hydrologic Soil Characterization in Palmdale, CA	
A	59.90%
B	20.30%
C	6.20%
D	11.80%
Undefined	2.00%

3.4. Pricing Models

The pricing of water is a complicated issue. The introduction of large scale water distribution systems focused primarily on ensuring individual access to safe drinking water. This policy reflected, at the time, a recent spate of urban epidemics which were distributed through a tainted water supply. Therefore, contingent on a secure and renewable water resource, the only binding constraint to the water utility was the cost of distribution. As distribution systems became larger to ensure distribution to growing populations, water had to be secured from sources further away, and a two part pricing system arose. The household water bill contained two parts, a fixed connection fee which reflected fixed distribution costs, and a constant marginal price per unit of water. As water resource constraints became more persistent it was necessary that household marginal prices reflect the marginal social cost of water use. This led to a tiered pricing schedule for water, indicated by increasing prices for higher units of water use. On a large scale, this may be effective to ensure that costs are recovered from consumers for water use. However, a two-part tariff with an increasing tiered pricing schedule assumes that all households are the same. In order to refine the pricing schedule, household information was needed to determine the need for each household. For instance households living in multifamily residences require water primarily for personal consumption while households in single family residences may require water for irrigation. Therefore, the need for the latter household is higher than for the former. This line of reasoning led to the water budget rates, which differ from the tiered pricing schedule in that they take into account household characteristics, including number of residents, lot size, irrigable area, etc., to determine the size of the units for each price tier, for each household.

To many it seems sensible that those who consume the largest quantities of water should face a higher cost given the high cost of developing new resources to fulfill local demand. However, there are a number of distributional issues involved with such a pricing policy. First, the implicit costs of conservation may be borne by those who cannot afford higher marginal units of water, while those who are better off may face a price increase but have no need to change their habits as long as they are willing to pay. While this may hold for most goods, in the case of water, this is politically unacceptable. Second, the availability of low priced water has led to a certain development pattern, specifically, a low density housing distribution with large yards and/or pools all of which require irrigation. Given that roughly half of all urban water is used for irrigation (See Hanak and Browne (2006)) this could cause an outcry among homeowners.

A comparison of the tiered water rates in each reference city is indicative of the local economies. Palmdale has the lowest price for first tier water at $0.73, and Riverside has the most expensive at $1.14. Riverside on the other hand has the lowest top tier water rate at $4.10, compared to Palmdale's $5.81 and Irvine's $12.60. Therefore, Riverside has the flattest increasing block rate while Irvine clearly has the steepest. What is lost in these numbers is the type of usage. Palmdale and Riverside both retain remnants of their agricultural past, therefore, exceedingly high prices for top tier water would place a large burden on farmers. Irvine's prices reflect a more severe penalty to wasteful users, which is reflective of the cities ability to implement a financial penalty which would be politically impossible in Riverside or Palmdale.

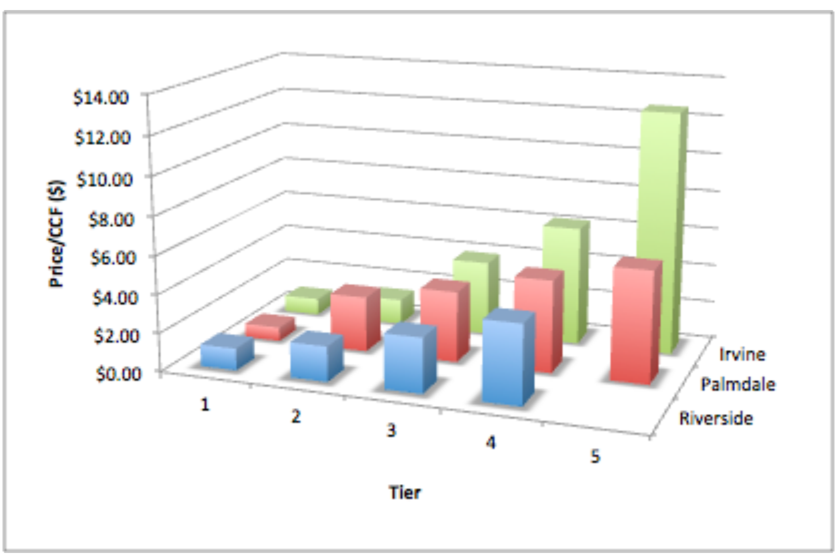

Figure #: Water Pricing Schedules for Riverside, Palmdale and Irvine

The prior discussion focused on the role of water pricing as it affects short term concerns, in particular, cost recovery and aggregate demand minimization. However, water conservation naturally has a long term, dynamic component, reflected in future population growth and uncertainty about future supply given a number of factors, including climate change. It is therefore important to understand how pricing of water can lead to long term habit formation with respect to households and water use. There is some indication that the increased marginal prices reflected in the water budget rate and tiered pricing schedule lead to lower aggregate water demand. Baerenklau et. al. found that the introduction of water budget rates by Eastern Municipal Water District in Southern California led to a 17% reduction in aggregate water use from the periods prior to the adoption of the rates. This provides some support for the theory that appropriate pricing of water can ensure long term sustainability of existing resources. However, water pricing is a politically charged issue whose adoption often takes years to implement. This largely rules out a more flexible pricing structure that is able to take into account present environmental or social conditions such as a drought or large scale local population growth.

Concerning the quantitative analysis each city is ranked on two measures: Tiered Pricing and Water Budget Rates. The first analyzes to what extent each city uses an increasing block rate pricing structure. The second is to what extent water budget rates are utilized.

3.5. Rebates

Water suppliers have generally accepted that rebates can be used to promote water efficiency to homeowners, commercial and industrial entities. The primary purpose of rebates is to promote system upgrades from old, outdated devices, to modern, high-efficiency devices. Rebates act as a subsidy to reduce the initial costs of the upgrades. In addition to the environmental benefits, upgrades also reduce the entity's water bill. In most cases, water suppliers see the worth of rebates to be equivalent to the amount of water supply they otherwise would have to secure.[AD1] Due to these views; most water suppliers have some form of rebate systems.

The City of Riverside has outlined in their GAP a goal of promoting efficient water use in commercial, industrial, and home sectors. To help accomplish this goal, they joined the SoCal Water$mart program, with RPU providing additional rebate programs. The RPU rebate program is funded by the utility itself and provides rebates only for homeowners within the service area.[AD2] The SoCal Water$mart program is funded by Metropolitan Water District (MWD) of Southern California as well as its 26 partner agencies in Southern California. Two of these agencies are Western Municipal Water District, which serves part of the City of Riverside, and Municipal Water District of Orange County, which is a member agency of Irvine Range Water District (IRWD), which serves the City of Irvine.[AD3,AD4] The funds for the SoCal Water$mart program are not separated out by district, or agency, but rather assembled into a general fund which is then used for the rebate process. This allows for the program to provide a large variety of rebates. PWD uses its own rebate system, which is available for both homeowners and commercial entities.[AD5]

The three rebate systems share many similarities for homeowners. RPU and PWD provide five different rebates for their homeowner clients, while SoCal Water$mart provides seven different rebates.(Figure ADHAS) In all cases, the customer is limited to a single rebate per device. The biggest difference between the three systems is that SoCal Water$mart system provides an additional nine rebates aimed at commercial and industrial entities. These rebates vary widely from urinals, to vacuum pumps and connectionless food steamers. The commercial and industrial entities are limited to $50,000 per customer, allowing for a larger number of retrofits to older buildings and infrastructure. It is important to note that the devices that are eligible for rebates are also the devices that can provide the largest water savings. For example, the connectionless food steamers reduce water use 95%, and the Ultra Low Water Urinals and Zero Water Urinals can reduce water use by 75%. (Table Efficiency)

The rebate systems available to homeowners, in all three locations share similar rebate types and limitations. All three systems provide a good diversity of rebate for devices with significantly higher efficiency then their older counter parts, earning them a score of +1 in rebate diversity. However, the rebate systems comes short in availability due to limitation of a single rebate per device, reducing the overall effectiveness of the rebates. This limitation leads to a score of -1 for availability of rebates for home owners. The SoCal Water$mart system is unique as it also covers industrial and commercial entities which provides large variety of rebates with high efficiency, and provides large availability for these rebates, therefore earning a rating of +1 in all areas for commercial and industrial rebates. Since RPU uses then SoCal Water$mart system for commercial and industrial rebates it shares same scores, however since RPU does not provide any rebates for commercial and industrial sectors they receive -3 across all fields.

<table>
<tr><th rowspan="2">Equipment Type</th><th colspan="3">Rebate System</th><th rowspan="2">Water Use Reduction (%)</th></tr>
<tr><th>Water$mart</th><th>RPU</th><th>PWD</th></tr>
<tr><td>High-Efficiency Toilets</td><td rowspan="6">Home + Commerical</td><td rowspan="5">Home</td><td rowspan="5">Home + Commerical</td><td>20</td></tr>
<tr><td>High-Efficiency Washing Machines</td><td>47</td></tr>
<tr><td>Irrigation Controllers</td><td>24</td></tr>
<tr><td>Rotating Nozzles for Pop-up Spray Heads</td><td>29</td></tr>
<tr><td>Turf Removal Program</td><td>100</td></tr>
<tr><td>Soil Moisture Sensor Systems</td><td rowspan="11">Commerial Use Water$mart</td><td rowspan="11">Not Available</td><td>50</td></tr>
<tr><td>Rain Barrels</td><td>Home Only</td><td>95</td></tr>
<tr><td>Ultra Low Water Urinals and Zero Water Urinals</td><td rowspan="9">Commerial Only</td><td>75</td></tr>
<tr><td>Connectionless Food Steamers</td><td>NA</td></tr>
<tr><td>Air-Cooled Ice Machines</td><td>NA</td></tr>
<tr><td>Conductivity Controllers</td><td>67</td></tr>
<tr><td>Dry Vacuum Pump</td><td>56</td></tr>
<tr><td>Laminar Flow Restrictor</td><td>29</td></tr>
<tr><td>Plumbing Flow Control Valves</td><td>NA</td></tr>
<tr><td>Large Rotary Nozzles</td><td>NA</td></tr>
<tr><td>In-Stem Flow Regulator</td><td>NA</td></tr>
</table>

Table 1asdasd: Will label once we get all tables/plost in…

3.6. Landscaping

Mandates are an important factor in reducing water consumption by homeowner actions. Certain areas allow only particular landscapes, a concept similar to that found in a few homeowners' associations. However, research showed that all three cities made mention of reducing water consumption through landscaping. The city of Riverside explicitly states in the GAP their intention to modify landscape guidelines. Currently, the municipal code only suggests the use of drought tolerant landscapes. The municipal code does provide guidelines for landscapes that adhere to the water budget for that property [TW1]. Calculations based on regional precipitation are the main factors that are used to determine the types of plants that are suitable. Although not guaranteed, these measures should decrease consumption, assuming that homeowners will adhere to the recommendations. PWD effectively utilizes concrete terminology to describe its mandates, including the water efficient landscape ordinances that prohibit new residences from having large turf grass areas. In addition, PWD requires new residences to submit a landscape documentation package for approval [TW2]. The City of Irvine's Sustainable Landscaping Guideline Manual strongly suggests limitations on the amount of turf grass per property and states landscaping should be based on the water budget of the property, similar to that of RPU [TW3].

The ease for residents to access information addressing the transition from turf grasses to drought tolerant landscaping is another important component of reducing water consumption. While both RPU and IRWD have separate websites dedicated completely to conservation measures, PWD has its information integrated into the main utilities website. The RPU website is lacking detailed information on the benefits of drought tolerant landscaping and beginner's information for homeowners who are unfamiliar with the many details regarding landscaping. IRWD provides a step-by-step guide beginning with background information of drought tolerant landscaping which then proceeds to installation methods. PWD's website flows smoothly through similar information. IRWD and PWD both provide galleries of landscapes that are aesthetically appealing and also maintain water efficiency goals to further assist homeowners in beginning the transition. Upon first glance, PWD has a small gallery, but after a deeper search, a more complete gallery can be found associated with their "Cash for Grass" rebate program. IRWD's website is a good example for the ease of accessing useful information, while PWD excels at providing good background information and detailed photo galleries.

Lastly, considering customer feasibility, all three cities offer rebate programs of $2.00 per square foot of turf grass being removed. All three require that the grass being removed must currently be irrigated and alive; however, PWD makes the distinction that if these conditions are not met: a graduated system based on overall grass health will be applied. RPU and IRWD present clear information including a frequently asked questions section and easy links to rebate applications. PWD requires free online or in person training for the "Cash for Grass" program in order to qualify for the rebate. PWD sets a great example for costumer feasibility, most notably for their extra effort to accommodate various lawn conditions.

3.7. Education

Previous research shows that lack of information concerning water conservation practices and technologies [4 DH], spurious assumptions about the quality and sustainability of the water [5DH], and skewed perceptions of their own water usage [6 DH] are significant causes of wasteful water practices. Thus, effective sustainability initiatives should involve programs promoting more sustainable behavioral change in the city's population addressing these key habits wasting water. As such, we have added a city's environmental education programs as an indicator of a city's overall sustainability.

IRWD's water education plan is well established, initiated in the 1970's and funded through the IRWD and a partnership with an independent science center [5DH]. The IRWD boasts a large budget for promoting water conservation [12DH]. This budget allows the city to implement programs that are otherwise unavailable, or more limited, in the other two cities discussed. Nevertheless, Irvine education programs incorporate several interesting methods and programs cities with lesser budgets can adopt. IRWD's water education plan is available to classes ranging from Kindergarten through 8th grade [14DH]. At the kindergarten to 6th grade range, the programs incorporate interactive games that encourage student exploration and participation during classroom presentations [5DH]. 6th grade through 8th grade classes engage in hands-on experiments in which children explore the water quality and sustainability issues with the independent science center. Additionally, Project WET (Water Education for Teachers) provides training for teachers to promote water conservation independently through the teacher's classrooms [5DH]. At all levels, Irvine city's programs show a significant commitment to instilling a sense of environmental stewardship and water conservation in its population.

Research shows that programs attempting to instill sustainability as a part of the student's continuing frame of mind are most effective [7DH], which would require multiple lessons to exceed expectations for water education programs [8DH]. A similar system existed in Irvine, spanning two semesters that focuses on the cultural and local ecological goals, though it was reduced due of budgetary concerns. Despite the reduction, Irvine's program uses its resources efficiently by training teachers to continue pro-environmental education beyond the presentations and experiments provided by the IRWD. In general, Irvine's water education programs are highly encouraging. The programs are based on solid principles and well funded. As a result, Irvine's education program provides a reliable expectation of achieving the goals for which it was implemented, and exceeds at promoting sustainable attitudes and behaviors.

The evaluation of Riverside city will focus on Riverside Public Utility (RPU). While the RPU does not possess the same financial backing as the IRWD, its newer program uses innovative practices in a promising educational program. RPU's water education program began in 2011, funded through RPU's public benefit fund with a budget 20 times higher than the previous year [1

DH]. The program brings experimentation kits and trained water professionals to 5th grade classrooms within the Riverside Unified School District and the Alvord School District. The educational program consists of a prezi presentation on the water cycle and how people can contribute and alter it followed by one of three active lab experiments [1 DH]. The active lab experiments involve creating a model aquifer, watershed, or terrarium out of household objects. Through these models, the students are then able to test how different alterations to the environment, such as pollution, can affect the water system as a whole [1 DH]. Following the one day lesson, a “science loan kit” is left with the class for two weeks that includes other engaging labs and activities for further, student-directed, exploration of water topics to continue after the RPU lead visit. Some of these labs include constructing a water filter from sand and charcoal, and water testing kits that can be used to test water quality from local water sources. In order to address non-student populations, Riverside city produces the “green power report” radio show promoting environmental behaviors through celebrity endorsement. Overall, this program grounds itself in a strong theoretical basis that could a potentially increase water conservation behaviors significantly in younger populations.

The program utilizes several aspects that make it an interesting, potentially effective, method of increasing motivation and awareness of water conservation practices. Educational measures are more effective when originating from a local, learner centered, initiative that is better able to focus on the cultural and social aspects of the targeted population [2 DH]. This program, locally funded and run, provides opportunities for children to create models of their local ecosystem in the form of model watersheds, as well as first hand interaction through the water testing kits. Providing context and self-directed exploration in educational materials can significantly increase motivation and interest in the learned subject [3 DH]. Active participation and context-based learning of the material potentially motivates students to engage in water conservation as continuing behaviors. Work by Louise Chawla [4 DH] shows that activities increasing the student’s perceived competence and emphasizing the consequences of the student’s actions are powerful motivators in developing environmental volunteerism later in life. As a result, this water education program contains all of the aspects necessary to motivate environmental volunteerism. Overall, RPU’s water education efforts exceedingly meet the requirements for a sustainable city. Despite the encouraging program, it is available only to 5th grade classrooms, and so Riverside city could improve its programs’ effectiveness by expanding to other age groups.

Palmdale city’s education programs, though incorporating various interesting and potentially effective methods despite its short history, contains greater areas for improvement comparative to Riverside and Irvine. Palmdale city founded its water conservation education initiative in 2012 [10DH]. The initiative is available to a wide variety of grades, from Kindergarten through high school [10DH]. The wide range of classes provides opportunities for multiple age groups to learn about water conservation. PWD’s education programs consist primarily of large assemblies from animal mascots [10DH]. These larger assemblies provide an inexpensive method to present information to a wide audience, but do not provide the deeper student participation or exploration that may motivate behavioral changes towards more conservative habits [2,3DH]. Yet, PWD provides opportunity for people to gain these type of personal involvement through tours of their water facilities. These tours actively engage populations in water treatment, though only 6 are available to the public annually [11DH], thus limiting the populations able to benefit from these tours. In this respect, Palmdale does not show much innovation in their water sustainability education programs. The bulk of Palmdale's efforts go to publishing newsletters, mascot advertising, and townhall meetings [11DH].

PWD does not possess the affluence or budget of IRWD or RPU, with a 5 thousand dollar budget [11DH] to the next lowest budget of 25 thousand dollar budget in Riverside [12DH;13DH]. Despite this low budget, PWD organizes various competitions to increase environmental conservation. Some appear to be relevant to water conservation, such as essays on native water saving plants for grades 4-6 or science projects focusing on water for grades 7 and up. Conversely, others are not especially relevant, such as coloring a garden available from Kindergarten to grade 3. All of these contests award monetary rewards for winners. While not as effective at promoting lasting change, these extrinsic motivations may initiate interest in water conservation and promote tangential learning. Thus, Palmdale city represents educational programs that may be marginally successful, but are less comprehensive than the other cities discussed in this paper. Palmdale could benefit from investing in programs that allow for independent promotion of environmental behaviors in order to more efficiently spend their budget. Overall, Palmdale could improve in some areas, notably increasing the comprehensiveness of programs and teaching methods they employ, in comparison to the other cities discussed in terms of promoting conservation.

In regards to populations served, Irvine and Palmdale offer programs to most, if not every year, of compulsory education, earning a (+1), due to students at many age ranges benefitting from the program. while Riverside reaches only 5th grade students, restricting the potential effectiveness of programs, and thus receiving (-1). All cities offered comparable, and sufficient, variety of programs covering the school water programs, and general population outreach comprised of social media and mail programs, each receiving scores of (0). Yet, in the school education programs, Riverside and Irvine cities receive scores of (+1) in their program's comprehensiveness and teaching methods, providing comprehensive curricula covering the water cycle, conservation, and local ecosystems utilizing active and engaging teaching methods. Palmdale, without commensurate resources, receives a (-1) in these categories due to the surface and non-active engagement in educational programs provided to Palmdale schools.

4. Evaluation

Indicator	Irvine	Riverside	Palmdale

Water Quality			
Drinking Water Quality			
a. Meet regulatory compliance	1	1	1
b. Resources devoted for quality control	1	1	0
Groundwater Quality	0	-1	0
Wastewater Quality			
a. Ability to reduce SSO	0	-1	0
b. Wastewater reduction programs	1	1	0
Recycled Water			
1. Ability to Produce RW			
a. Facility	1	0	-1
b. Permit	1	1	1
2. Production			
a. RW produced/WW collected	1	0	-1
3 Use of RW			
a. V RW used/V RW produced	1	-1	-1
b. Wholesale	0	-1	-1
c. Recharge	0	-1	-1
d. larger customers/irrigation	1	-1	-1
e. Other environmental	1	-1	-1
f. Delivery to customers	1	-1	-1
4. Future projects			
a. Financial planning/feasibility	1	1	0 or -1
b. Engineering plans			
i. Designed	0	1	1
ii. Approved by city council and water district board	1	1	?
iii. Plans are best effective use	1	1	?
Environmental Protection			
Regulation Requirements and Availability of Design Guidance and Implementation	1	0	-1
Contribution to Growing Knowledge Base	1	1	-1
Achieving Fullest Potential of LID Technology Based on Geological Environment	1	0	-1
Pricing			
Tiered Pricing	1	1	1
Water Budgets	1	0	1

Rebates			
Diversity	1	1	0
Audience	1	1	0
Saving Potential	1	1	0
Landscaping			
Legal Mandates	1	1	1
Access to useful Information for Transition	1	-1	1
Homeowner Feasibility	1	1	1
Education			
Populations Reached	1	-1	1
Program Variety	0	0	0
Program Comprehensiveness	1	1	-1
Teaching Methods	1	1	-1
Sum			
	27	**7**	**-4**

5. Conclusion

Though our collaborative research on water conservation and sustainability in California is fundamentally evaluative, we have sought to compare each city's water conservation measures with our own set of indicators, *not* between one another. As with urban infrastructures generally, physical means of conveying water and the immaterial means of regulating its consumption meet with pre-existing local conditions and systems of value "on the ground." They also have local effects, which radiate outward (e.g. in the form of total state water consumption as an aggregate of the consumption of individual, industrial, and ecological users) (Larkin 2013).

As such, we emphasize that this collaborative endeavor seeks to operationalize a set of indicators regarding sustainable water use. These indicators should not, however be allowed to stand alone, but rather, should be reshaped and revised within local contexts. That is, while the indicators provide a basis of comparison, which could illuminate potential points of improvement, they do not provide ready-made mechanisms by which centralized governmental bodies should seek to impose more stringent water consumption standards. A significant critique toward the 20X2020 plan is that it places across-the-board reduction demands on municipal water agencies, regardless of standards of living (Waldie February 2014)[7]. For example, while statewide municipal

[7] http://www.kcet.org/updaily/socal_focus/commentary/where-we-are/in-a-season-of-drought-where-does-the-water-go.html

water consumption has been steadily decreasing, substantial reductions in use are likely to be more painful in the low-income community of Palmdale compared to the relatively high-income community of Irvine (State Water Quality Control Board, Public Policy Institute of California – ppic.org).

Therefore, while it is appealing to suggest that consumption-reduction mechanisms can be devised and transported to vastly different contexts, differences in standard of living (which impact not only the *effects* of reduction, but whether or not a resident is *able* to implement more efficient devices – often an unreasonable expectation for renters as compared with home-owners), as well as discrepancies in overall water consumption rates between urban and industrial agricultural agencies should factor into future analyses regarding water sustainability.

While the efficiency gains of local municipal water districts are significant, recent projections of drought severity suggest that they might not be significant enough to make up for losses as a result of many farms switching to more water-intensive perennial crops (Schwabe, course lecture).

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