Technical Memorandum:
Estimating Benefits of the Pure Water Soquel Project

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The Technical Memorandum presents the methods used to estimate the costs and benefits of the Pure Water Soquel Project (the Project). Work took place in June-August, 2018 on behalf of the Soquel Creek Water District. Brent Haddad, MBA, Ph.D., is a Professor of Environmental Studies at University of California, Santa Cruz, and Bryan Pratt is a Doctoral Candidate in Economics at University of California, Santa Cruz.

Cost Analysis

The Project's engineering consultant was Brown & Caldwell, which provided data on capital and operations and maintenance (O&M) costs. Using these estimated capital costs and O&M costs, we applied a net present value calculation using an industry standard 5% discount rate. Capital costs of the Project have a central estimate of $90 million in 2022 dollars, with a range of $63-135 million. Discounted at 5% to 2018, the central estimate is equivalent in today's dollars to $74 million. Annual O&M costs are estimated at $1.9 million in 2017 dollars. Discounted at 5% through 2050 (33 years), this is equivalent to $30.4 million. This amounts to a net present value of $104.4 million in project costs combining both capital and O&M costs.

Benefit Analysis

One of the most common forms of evaluating the benefits of water infrastructure projects is to calculate or estimate the cost of more expensive sources of water that were avoided by the use of the project in question. This represents the benefit to the water utility itself from securing a given water supply. For many water districts in California, this is the cost of importing water.[1]

However, some water districts have no readily available or feasible alternatives. This is the context of Soquel Creek Water District and its proposed Pure Water Soquel water recycling/groundwater replenishment/seawater intrusion prevention project. Several decades of analysis and regional efforts at implementing other options have not resulted in any substantial water supply project coming on-line. Impediments to alternative projects range from geographic to economic to technical to political. As a result, the most likely no-project

[1] "Examining the cost of building and operating a water purification system to provide a new source of water for an arid region." Orange County Water District. https://www.ocwd.com/media/1854/white-paper-cost-of-gwrs.pdf
Also: "Groundwater Recharge Feasibility Study." City of Lancaster.
http://www.ladpw.org/wwd/avirwmp/docs/Lancaster%20Report.pdf
"Final Report: East County Advanced Water Purification Program Planning Study." Kennedy/Jenks Consultants, prepared for Padre Dam Municipal Water District. https://www.padredam.org/DocumentCenter/View/2262/East-County-Advanced-Water-Purification-Program-Planning-Study?bidId=

future involves complying with the Sustainable Groundwater Management Act of 2014 through severe reductions in groundwater pumping, thereby reducing the District's water supply from 3,800 AFY to 2,300 AFY for several decades.

It is therefore necessary to use an alternative measurement of project benefits. The analysis is divided into four categories: (1) benefits to residential customers, (2) benefits to commercial businesses, (3) environmental benefits, and (4) outside of district benefits. Since the utility is by law not a profit-making enterprise, we can expect little or no benefit accruing to the revenue-neutral utility. In addition, we consider the impacts on the employment and housing markets, locally. For these impacts, we provide quantifiable but not monetizable benefits (e.g., jobs losses avoided, housing units provided). All numbers over one million are rounded to the nearest million.

Residential benefits

Roughly eighty-five percent of all District water deliveries are to residential accounts. We estimate the value that District customers derive from the water they purchase. Assuming that (1) consumers derive a benefit from water for which they are willing to pay and (2) that water is allocated through a price-based mechanism, we can use the revealed preference theory to calculate the benefits to consumers and to the utility from an increase in the total available supply.

The pivotal economic concept that undergirds this analysis is that of consumer surplus. We assume that any household will only purchase water (like any good or service) when the marginal benefit of purchasing that water exceeds the price the household must pay. The difference between the amount that a household pays for a given quantity of water and the dollar value of the water's benefits to the household is the consumer surplus. Aggregating across all residential consumers, a demand curve can be drawn that represents the marginal willingness to pay for a given quantity of delivered water. Notice in Fig. 1 the blue area above the price of the water and below the demand curve, labeled *Gain*. Its size tells us the benefit of the delivered water to the consumers, net of the utility's expenditures to provide the water.

Revealed preference theory

The concept of revealed preference can be traced to Paul Samuelson, who introduced the notion in a paper on the theory of consumer behavior (1938). Samuelson notes that this concept can be used to estimate the underlying preferences, that is, the demand curves, of consumers even when we cannot observe their actual buying behaviors in markets. Samuelson and others[2] explain how we can use observed market transactions to estimate the demand

[2] Varian (2005) provides an excellent review of the revealed preference literature, including Houthakker (1950), Rose (1958), Newman (1960), Uzawa (1960), Afriat (1965), Richter (1966), Yokoyama (1968), Chipman et al. (1971), Stigum (1973), and Sondermann (1982).

curve for a given item, which traces the marginal benefit to consumers from consuming an additional unit. Countless economic valuation projects have used this method.

The general approach of measuring revealed preferences must be adapted to each specific market context. Water presents its own special case as a good that households purchase from utilities with a price that increases as the amount purchased increases, and then resets each month (that is, increasing block pricing). In seminal papers on the topic, Koichiro Ito, a Professor at the University of Chicago, uses independent variation in pricing to generate evidence that consumers make water purchase decisions based on average prices, rather than marginal prices, in both the water market (2013) and for other purchased utilities more broadly

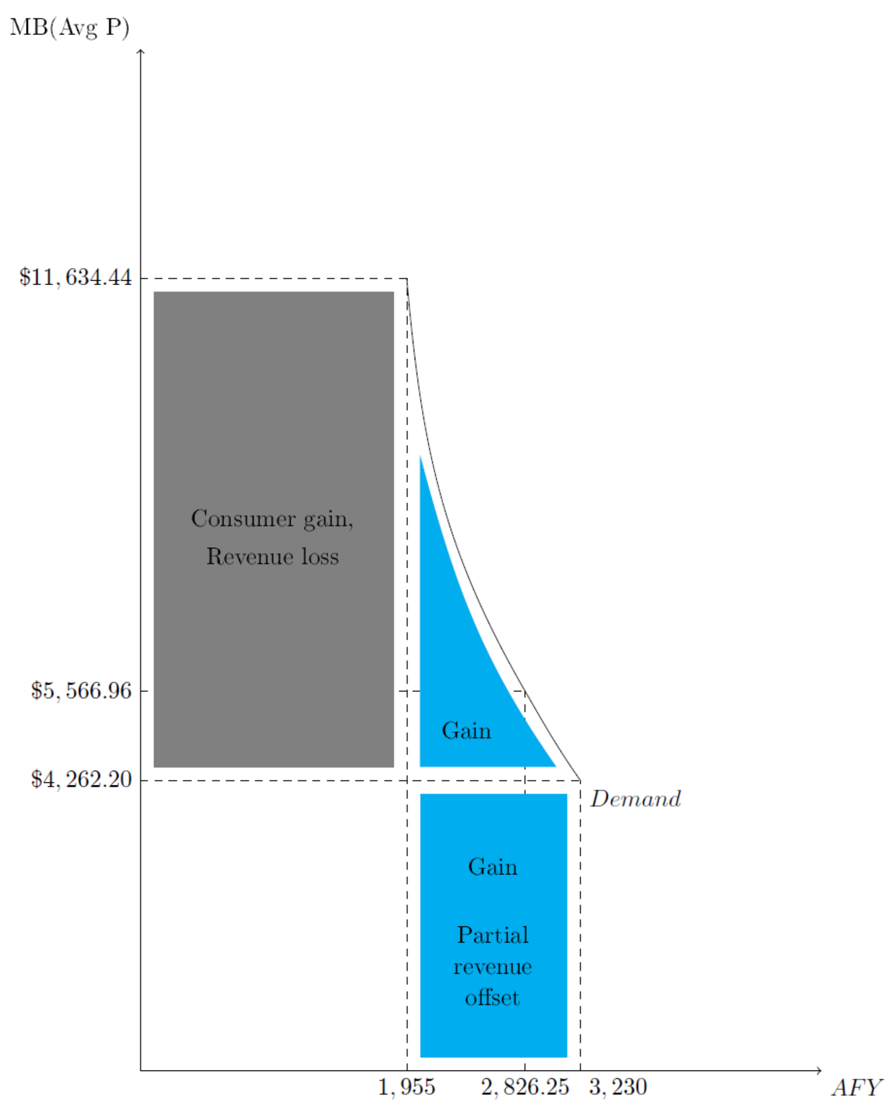

Figure 1: Benefits Calculation

(2014). The direct implication of Ito's results is that consumers set the marginal benefit they derive from consuming a unit of water equal to the average price of consuming that unit of water. With increasing block rates, the average and marginal prices of water can differ substantially. In line with Ito's findings, we assume that the observed equilibrium in the market for potable water represents the intersection of the supply curve with the average price.

Price elasticity of demand

The price elasticity of demand is the measurement of how much less of a good someone will purchase when the price goes up. When it is easy to switch to a different product, the good's price elasticity is considered to be very high. But if the good is essential and has no substitutes, people will continue to buy roughly the same amount even if the price goes up. Those goods are considered to be price inelastic. Water is considered to be moderately price inelastic since residences can only cut back to some extent when the price of water rises. It is necessary to first estimate the price elasticity of demand for water in order to then estimate the value of benefits residents derive from their water use.

We took estimates of consumer price elasticity from District data and applied them to a constant elasticity demand curve estimated at the current price and quantity. Recall that the easier it is to cut back on water consumption, the less one needs (and therefore values) the water. Stated differently, the more inelastic one's demand for water, the more one values water as a commodity. Estimates of residential demand elasticity range from approximately -0.1 to -1.14, with the most robust estimates closest to -0.3 (Ito, 2013; Wichman 2014, 2016). The neighboring City of Santa Cruz in its 2015 demand forecast identified -0.25 as the average year-round demand elasticity among its customers, with higher elasticities in a severe (stage 3) drought (M.Cubed 2015, p. 14 and Table 9).

These estimates are derived from relatively small changes in the price, while our Soquel Creek analysis considers potential variation of prices by as much as several hundred percent. Using historical SqCWD data, we estimated that the consumer price elasticity is likely no more elastic than -0.5, though potentially lower (closer to -0.25). This estimate is based on calculations using confidential billing data at the account level from 2013 through 2016. They are also consistent with Ito (2013) and Wichman (2014, 2016).

Our calculation uses -0.5 while others, including Santa Cruz, use -0.25. This appears to suggest that customers of Soquel Creek Water District will demand less water than other customers given the same price signal, meaning they value water consumption less than others. However, this is not the basis for our use of -0.5 and not the appropriate interpretation of our estimates. The context of our analysis is different in three important ways. First, a far greater drop in consumption is required in the District compared to other cases and compared to what has been modeled in all the other studies. While the most recent drought involved extensive conservation, consumption never fell close to the recharge target of 2,300 AFY. Understanding that the purpose of the price increases is to massively restrict demand, customers may vigilantly implement demand-reduction behaviors beyond what the other models predict.

Second, unlike a drought, the desired reductions are not temporary but effectively permanent (multi-decade). Knowing this, customers may implement effective long-term changes in consumption behavior rather than temporary accommodations that do not yield as much long-term conservation.

And third, from a practical perspective, water demand reductions are achieved through a combination of both price-based and non-price based actions. Non-price-based actions, such as required conservation technologies, take the burden off of pricing to restrict demand, but obscure what the price signal tells us about how much consumers value water. The marginal benefit curve may actually be more elastic than estimated through studies of small price changes. Overall, given these sources of modeling uncertainty, we find it appropriate to utilize an elasticity (-0.5) that provides conservative estimates of the benefits of the Project, noting that utilizing the more inelastic -0.25 would have added $50 million to our valuation of Project benefits.

As shown in Figure 1, utilizing 2016 data, we applied this elasticity estimate to an observed residential production of 2,826.25 AF and an observed median Single-Family Residential average price per AF of $5,666.96. Under the assumptions that the District consumes 2300 AFY sustainably, the Project adds 1500 AFY, and residential demand is always 85% of total demand, then 1955 AFY and 3230 AFY are 85% of total demand with and without the Project. The value between these two points under the demand curve represents the net gains to the District from residential water supply.

Utility behavior and revenue change

The next component necessary to calculate the direct benefits of additional supply is the behavior of the water district. We use an approach that is different from the actual process of rate-setting but allows us to take advantage of what we know about consumer demand. Given that the District's mission is to reliably and sustainably meet customers' demand for water, we assume that the District will set prices such that total consumption is equal to the available supply. The District will charge prices that are low enough to not further reduce consumption below the available supply, but the District will not reduce prices to the point that demand outstrips supply.

The practical implication of this method is that the equilibrium prices and quantities are found through the intersection of the demand curve with the supply constraints imposed for the sustainability of the Basin. As shown in Figure 1, in order to generate enough curtailment to comply with 2,300 AFY, the District would need to raise prices to nearly $12,000 per AF until the Basin is no longer overdrafted. If the District allows annual production of 3,800 AFY, the District could lower prices to near $4,000 per AF.

For full consideration of the impact of the Project on the market for water, we must also consider the impacts of these different scenarios on the budget of the utility. Using our model, utility revenue is estimated to decline some as a result of price elasticity related to the Project, and this consideration therefore reduces the total Project benefits. As illustrated in Figure 1, the revenue lost relative to the cutback scenario (upper left rectangle) is not fully offset by increases in revenue from increased water sales (lower right rectangle). This follows directly from the relative price inelasticity of demand for water, which both implies large price changes are necessary to induce changes in consumption and ensures that lower sales volumes for a utility will result in higher revenue if generated through higher prices. In reality, since the District does not actually base its pricing on consumer demand behavior, its revenues are not threatened by the Project. Its future revenues will be determined by a broader process involving public input and the Board of Directors.

Calculating net benefits

Having created a District-specific residential demand curve for water, we can then estimate the gains to the service area from the increased supply (the blue in Figure 1). The gray rectangle is passed from the utility to consumers, but this has no net impact on the overall benefit of the Project. The blue area that resembles a triangle is the benefit customers derive from their additional water purchases over and above the purchase price. The blue rectangle is the benefit to customers that is paid to the utility through their water bills. We estimate the combined value of these gains for every year from 2019 through 2045, when the Basin is projected to recover, although groundwater modeling suggests replenishment will need to continue even after 2045. During the years before the Project is operational, the ability to constrain future net withdrawal would enable the District to maintain pumping, which would otherwise be contrary to the restoration of the Basin. We then use an industry-standard 5 percent discount rate to normalize the benefits to 2018 dollars and aggregate the benefits over time.

Under the assumption that the District will adapt total pumping to meet aggregate demand forecasted by the 2015 Urban Water Management Plan update, the NPV of direct benefits to residential customers is approximately **$120 million**.

However, operating the Project while withdrawing to meet demand would lead to additional recharge beyond the No-Project Alternative, which would provide separate benefits, such as lowering the stress on other aquifers in the Basin, generating a faster recharge, or creating a surplus supply for mitigating water shortages. The environmental benefits section discusses these benefits.

Housing development moratorium avoided

In the absence of the Project, in addition to the costs to existing households from restricted consumption opportunities, the housing market would also be affected by a likely water service moratorium on housing development. The District already requires new development to purchase water demand offsets, and without an alternate source of supply, a moratorium on new development will be necessary until the Basin can be restored.[3] Based on District data and data from the Association of Monterey Bay Area Governments, a moratorium would result in roughly 2,100 additional housing units not being built by 2035 (Water Systems Consulting, 2016).

While such a moratorium would likely not be enacted immediately, the forecast data is only available through 2035, and the foregone construction after 2035 and before the Basin is fully recharged would vastly exceed construction before the moratorium, making this a very conservative estimate. As of 2015, the service area included 20,285 housing units, with a perennial problem of high housing costs and a lack of affordable housing.[4] According to Demographia, an Australian research group, "Santa Cruz, California, located in the San Francisco Bay Area, is the least affordable market" in the United States.[5] Demographia specifically points to restrictions on new housing expansion as a key driver of this crisis.

While the District is only part of a larger housing market, there is a shortage of housing units and, specifically, affordable housing units throughout the local housing market. These lost units, amounting to at least 10 percent of the existing housing stock in the service area, would contribute substantially to higher housing costs and possibly to homelessness. Allowing housing development to move forward at a sustainable pace with the Project would contribute to reduced pressure on the housing market and those struggling to find housing.

Commercial benefits

In order to generate a full accounting of the benefits, we also consider the impact on economic activity from the forced reduction of water deliveries to commercial accounts, leveraging both observed reductions in growth during the most recent drought and engineering estimates from prior studies.

While residential consumers comprise approximately 85 percent of water deliveries in the District, the commercial sector would experience substantial pain from long-term reductions. Calculating the lost economic activity for the District is difficult, in large part because the cutbacks that would be necessary to restore the Basin would exceed even the most aggressive short-term reduction plans whose effects have been studied. Fortunately, the San Francisco Public Utilities Commission (SFPUC) has conducted several analyses with the objective of determining the effects of severe cutbacks on the local economy. Moreover, their 2005 analysis incorporates several studies of relevance to the local area. In our analysis, we cross-verify observed impacts on economic activity during the most recent drought-induced curtailment

[3] See, for example: "Overtaxed Soquel Creek District Aquifers May Limit New Development Without Offsets." SqCWD, reprinted from the Santa Cruz Sentinel, Sept. 6, 2016. https://www.soquelcreekwater.org/news/latest-news/overtaxed-soquel-creek-district-aquifers-may-limit-new-development-without-offsets

[4] See, for example: "Major study shows Santa Cruz many paths out of housing crisis." Santa Cruz Sentinel, Nov. 29, 2017. http://www.santacruzsentinel.com/article/NE/20171129/NEWS/171129654

[5] "14th Annual Demographia International Housing Affordability Survey: 2018 Rating Middle-Income Housing Affordability." Demographia, Wendell Cox Consultancy. http://www.demographia.com/dhi.pdf

period with predicted impacts from engineering and survey estimates in the SFPUC 2005 report. In the San Francisco regional studies, economic damages get increasingly worse as water cutbacks increase. While the service area differs greatly from the larger San Francisco Bay area, our main assumption is only that the convexity of how damages increase as curtailment increases is similar in both areas. That is, damages from water shortages escalate proportionally in both regions relative to the size of the cutbacks. We use this assumption to scale observed economic activity under a 25 percent curtailment during 2014-2015 in the Santa Cruz – Watsonville Metropolitan Statistical Area (MSA) to projected damages under 30 percent curtailment, which is a conservative estimate of the actual level of curtailment that would be necessary, but was the largest calculated by SFPUC 2005.

The underlying data for this analysis include real gross domestic product and employment for the Santa Cruz – Watsonville MSA, the finest geographic disaggregation publicly available for such data.[6] In order to find estimates relevant for just the service area, we scale the aggregate numbers, calculated at the MSA level, by the portion of employment that the District's service area accounts for, as of 2010. The empirically estimated effects from the 2014-15 drought are driven by the policies of neighboring Santa Cruz Municipal Utilities (SCMU) given that the majority of the region's industrial and commercial accounts are located in that service area. As of 2016, SCMU had removed its most stringent conservation measures based on improving drought conditions.

For the differences in aggregate economic activity, we assume that economic activity in 2014 and 2015, during the most recent drought restrictions, would have otherwise grown by the average rate of 2013 and 2016. 2016 is a conservative choice in that the economy likely had not fully recovered from the previous two years of drought. More long-run averages are likely to incorporate confounding effects from the Great Recession, and data are not available beyond 2016. By this estimate, the most recent drought generated around $33 million each year in damages for the District's service area. Given that this was only an approximately 25 percent curtailment period, we scale this estimate by the ratio of the 30 percent reduction scenario to the 25 percent reduction scenario in SFPUC (2005). The result is $47 million each year through 2044, and the NPV of these avoided damages would be **$676 million**.

To verify that our estimates are reasonable, we also utilize the sectoral engineering estimates of curtailment under various levels of aggregate reductions. Matching on BEA-provided sector data and using 2013 levels of industry output as a baseline, we estimate that the preceding analysis would understate, if anything, the total damages associated with a 30 percent curtailment. This may be a result of the fact that businesses make necessary adjustments when truly faced with restrictions, but it also may be due to the fact that businesses outside the

[6] [1] U.S. Bureau of Economic Analysis, "Real GDP by metropolitan area (millions of chained 2009 dollars), Santa Cruz-Watsonville, CA." https://www.bea.gov/iTable/index_regional.cfm
[2] U.S. Bureau of Economic Analysis, "CA25N Total Full-Time and Part-Time Employment by NAICS Industry, Santa Cruz-Watsonville, CA." https://www.bea.gov/iTable/index_regional.cfm

service area but included in the economic data (that is, in Santa Cruz and Watsonville) were not generally required to conserve as much as residential customers in the most recent drought. In a long-term conservation plan, commercial customers will feel the damages of curtailment even more strongly, and the actual required curtailment would likely exceed 30 percent. This magnification may be tempered by the less industrial mix of users present in the District's service area.

With reduced economic activity, certain studies have sought to quantify the associated job losses. Using estimates from M.Cubed (2008) and employment figures from BEA, we estimate job losses of around 725, representing 3.8 percent of employment in the service area.

Environmental Benefits

Ideally, non-market valuation includes survey research in which respondents are asked their willingness to pay for benefits. Due to cost and time constraints on this project, we drew upon prior research and interviews with regional administrators (e.g., Griggs and Haddad, 2011), and our knowledge of the systems and models, to generate estimated values for all input quantities (summarized in Table 1). As with all non-market valuations, these numbers should be considered as representative of a range of possibilities.

The planned amount of groundwater recharge – 1,500 AFY – could lead to a net recharge beyond the District's needs, based on UWMP projections. Pure Water Soquel, operating at normal capacity, will restore the basin at a rate faster than the No Project Alternative. In the first six years of the evaluation period, the No Project Alternative (that is, severe cutbacks in pumping) provides greater annual recharge, after which the Project recharges more annually. The Project would result in more overall recharge by 2029 and leads to complete recharge of the basin sooner than the severe cutbacks alternative. The items listed below are risks that can be avoided by fully recharging the aquifer sooner than the No Project Alternative.

- A massive drought beyond modeled expectations (additional stored groundwater provides a buffer in a district with no other options);
- Accidental anthropogenic spills and contamination into aquifer near production wells (protects human health by diluting spills and other pollutants, and also providing additional pumping capacity at unaffected wells); and
- Failures in neighboring water systems, or water-intensive fire events, that require emergency water sharing (reduces the regional impact of unexpected curtailments or losses of water supply).

The value of avoiding the above risks can be calculated as option values, that is, calculating the value the region would place on having additional water to deal with such occurrences. Methodologically, we estimated the probability of each event happening once over a 27-year time horizon, and then divided by 27. We estimated the amount of additional water that would be consumed in the event, and we estimated the value per acre foot of the additional water at the time of the event, which would be substantially higher compared to normal non-emergency conditions. We then took the net present value of the annual benefits.

Option value	Probability of single event	Consequence (AF needed)	Benefit ($ per AF)
Extreme drought buffer	0.25	1,000	55,670
Fire protection/aftermath	0.1	2,000	55,670
Anthropogenic spill	0.1	2,400	22,268
Alternate scenario value	**Probability of scenario**	**Volume needed (AFY)**	**Benefit ($ per AF)**
Climate change impact reductions	0.1	200	27,835
Seawater intrusion risk reduction	0.3	200	55,670
Buffer for unexpected spikes in demand	0.25	200	16,701
Existence value	**Valuation ($ per AFY)**		
Stream baseflow accelerated recovery	50		
Improved resilience of spring/seep ecosystem	55		
Subsidence risk reduction	55		

Table 1. Input Data to Environmental Valuation. Source: Investigators' prior research, interviews, and knowledge of the systems and models.

Next, we identified three plausible alternative future scenarios for which additional stored groundwater would provide regional value:

- Climate change-related reductions in groundwater recharge are greater than modeled (provides a buffer to unexpected reductions in recharge);
- Seawater intrusion worse than modeled (retaining coastal pumping capacity protects water infrastructure investments and existing regional coastal land uses, such as agriculture); and
- Unexpected spikes in District demand due to new, unforeseen water-intensive economic activity, such as new state mandates for additional housing or housing law changes, or expanded cannabis cultivation (extends the response time to generate additional conservation and search for new supplies).

Preparing for alternative plausible scenarios has an insurance value, which we have estimated. We estimated the likelihood that the alternative scenarios would be realized, and the volume of water needed to make up the difference compared to the modeled scenario. We again generated a probability-weighted net present value of benefits.

We then turned to existence values, identifying three values that would benefit from accelerated groundwater recovery:

- Stream baseflow improvements (maintains the tourism economy that in part values flowing surface waters and in-stream environmental benefits);
- Improved ecological functions of springs and streams (accelerates the recovery of species and ecosystems); and
- Land subsidence results in damage to buildings and infrastructure (avoidance or reduced cost of repair).

We assigned an estimated existence value to each (dollars/AF), representing the amount, in total, the District and region would be willing to pay for the benefit. We multiplied the existence value by the annual cumulative amount of groundwater either below or above the targeted, or planned, recharge rate on a year-by-year basis and took the net present value.

In determining the rate of basin recharge compared to the planned recharge rate, we used long-term District demand forecasts supplemented by regular Project recharge starting when the Project is built, 2022, assuming no demand curtailments during construction. We also determined the average annual additional withdrawals, assuming that our scenarios (fire, extreme drought, anthropogenic spills, climate change, seawater intrusion, demand increases) turn out to be accurate, and removed them from the aquifer.

As a result, the overall existence value amount was negative (-$1.5 million) since more water is devoted to low-probability high-water-demand events than is provided as surplus recharge. A way to understand this number is that it would be much greater (that is, a larger negative value) in the absence of the surplus recharge. The other categories provide substantial District and regional net benefits: Option Value totals roughly $16 million; Alternative Scenario Value totals $68 million, resulting in overall estimated net environmental benefits **of $83 million** (rounded down).

Outside of District Benefits

In addition to the direct benefits of the Project to customers from additional supplies, the Project may generate benefits to water suppliers and water consumers outside of the District. We estimated that additional supplies to those pumping from the Aromas Red Sands aquifer could be conservatively valued at $4,000 per AF, an approximation of the marginal benefit of the last AF supplied to District customers in the 3,800 AFY production scenario. Given that the Project could make an additional 16-685 AFY available (ESA, 2018, Appendix D; the wide range depends on future demand in the District), this would result in $64,000 to $2.7 million in benefits per year. We project a reasonable scenario to be 420 AFY, near the mid-point, and using an industry-standard 5 percent discount factor, calculate **$24 million** in benefits. This approach assumes that making water available for use outside the District will not conflict with use of the water to provide environmental benefits. Some uses could reduce the amount of water available for future environmental benefits. If this occurs, then the $24 million would overstate the amount of benefit. This approach also assumes that in the no-Project alternative there either are no out-of-District benefits, or equal benefits flow across the District boundary as all parties work to restore the aquifer. By valuing the out-of-District water below the current in-District value ($4,000 vs. $5,667 per AF), we are accounting for the unknown future uses or use restrictions on the available water. Overall, the flow available could be much lower than we estimate if they conflict with other future in-District uses, while the value per acre foot could be much higher depending on the availability of alternative supplies. This emphasizes the wide range of potential values surrounding our estimate of $24 million.

Summary

Using this combination of methods, we estimate the Project total benefits to include both at least $796 million of direct benefits plus approximately $107 million in environmental and non-District benefits. This adds up to total monetized benefits of $903 million. Additional quantifiable benefits include avoiding a moratorium on development that would prevent 2,100 new housing units, and avoiding roughly 725 job losses, or 3.8 percent of employment in the service area. We compared monetized benefits to costs of $104.4 million to arrive at a benefit:cost ratio of 8.6.

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