Chapter 6

THE QUALITY OF BERKELEY'S WATER SUPPLY

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Introduction

The East Bay Municipal Utility District (EBMUD), which supplies Berkeley's water, has long been known to provide water of excellent quality. The quality of EBMUD's water is far better than what is required by the California Health Standards. It is also better than the quality of water provided by EBMUD's nearest neighbors, the Contra Costa Water District (CCWD) and the San Francisco Water Department (SFWD). The processes which contribute to the quality of EBMUD's water can be divided into two categories: natural and treatment. The natural processes are those which determine the quality of EBMUD's water sources, and treatment processes are procedures designed to purify the water after it enters the EBMUD system.

The projected rise in demand for EBMUD's water and the possibility that the District will be asked to annex additional territory or share its water with CCWD has prompted a search for a supplementary water source. Though EBMUD emphasizes its commitment to maintaining and, where possible, improving on its present water quality, these anticipated changes present significant problems. Among these problems is the scarcity of additional high-quality sources.

Historical Background

Berkeley's water was not always so clean. From roughly 1850 to 1923 both water quality and water supply were major problems for the East Bay (Noble, 1970). A series of private water companies supplied water to Berkeley between the years 1866 and 1923. All supplies were drawn from local sources, and often water was in short supply and of very questionable quality. In the early 1870s, the East Bay correspondent of the Daily Alta California wrote (Noble, 1970):

> If the water used in San Francisco were of a quality like that furnished Oakland, the cry over there would be for less instead of greater supply. It has such an offensive smell that, to say nothing of drinking it, it is not even 'goot for vash', and it is feared that the increased use of substitutes for the natural beverage of mankind will seriously affect not only the physical, but also the mental condition of the community . . . . The muddy condition and the terrible

> stench of the water now served Oaklanders renders it fearfully nauseating to the strongest of stomachs. Is there no remedy?

Suggestions for a municipal water supply go almost as far back as the East Bay's turbulent water history. However, it was not until 1921, when the Legislature passed a bill which specifically provided for a two-county East Bay district, that it really became feasible. A vote was held on May 8, 1923, and the people of the East Bay approved EBMUD by a very comfortable margin (Noble, 1970).

It is difficult to say precisely how much the poor quality of East Bay water had to do with the approval of the East Bay Municipal Utility District in 1923. Such causal assessments are always difficult in history. But, two things are certain. First, both water quality and water supply had been severe problems in the East Bay for over half a century. Second, people knew that something had to be done. The Oakland Tribune remarked editiorially (Noble, 1970) that "we are going to have to spend $70,000,000 one day soon." The question was whether a private company or a public utility was better suited to solve the East Bay's water problems. Arguments raged on both sides before the 1923 election. Proponents cited the numerous failings of past private companies, while opponents warned of the encroachment of socialism. In the end, the people made their choice. Almost sixty years of private water companies had brought no long-term solutions to either of the East Bay's water problems. After riding the rollercoaster for so long, the people of the East Bay, whether afraid of socialism or not, turned to public ownership to solve their lingering water problems.

The EBMUD System

EBMUD's water comes from two natural sources. The first and major one, accounting for roughly 90 percent of the water supply, is the Mokelumne River (Santiago, 1983, pers. comm.). The rest is runoff from the East Bay watershed (see Map, p. 44). All water from the Mokelumne source that is destined for domestic use is stored in Pardee Reservoir. From Pardee, the water flows through three aqueducts to the East Bay. At the East Bay end, the water either goes directly to a filter plant or to one of EBMUD's local reservoirs, where it mixes with water received from local runoff. EBMUD has seven filter plants. The Lafayette, Orinda, and Walnut Creek plants treat water directly from the aqueducts. Sobrante and San Pablo filter plants treat water from San Pablo Reservoir. San Leandro filter plant treats water from San Leandro Reservoir, and Chabot filter plant, which is on standby only, treats water from Chabot Reservoir.

Berkeley receives water from only the Orinda and San Pablo plants (Santiago, 1983, pers. comm.). The eastern section of the city receives Orinda water exclusively, while the western section receives a mixture of the water from both plants.

Water Quality

Water quality can be described succinctly in terms of five key parameters: minerals, particulates, cancer-causing organics, microorganisms, and aesthetics (EBMUD, 1983c).

Mineral content is often collectively described by a measurement of total dissolved solids (TDS). In-depth water quality studies also provide measurements for specific minerals. One of these is sodium, which in recent years has received a lot of attention because of its connection with hypertension and related heart disease. The Environmental Protection Agency, in response to a National Academy of Sciences study, has set a maximum level of 20 milligrams of sodium per liter of drinking water.

Particulates, or suspended solids are frequently measured in nephelometric turbidity units (NTU). Turbidity of 5 NTU is just visible in a glass of water. Suspended solids include any undissolved organic or inorganic materials.

Because of the links between air-borne asbestos and cancer, the possible health risks of water-borne asbestos are now being assessed. Although no standard presently exists, it is widely recommended that asbestos levels in drinking water be kept as low as possible.

The cancer-causing organics of most concern are the trihalomethanes (THMs), such as chloroform, a known animal carcinogen. Carcinogenic synthetic organic compounds (SOCs) can also end up in water supplies. Pesticides are among the SOCs.

Bacteria and viruses are microorganisms found in water that can cause disease. They are usually removed by means of a disinfectant such as chlorine.

Aesthetics mainly involves the taste and odor of water. Geosmin and methylisoborneol (MIB) are two organic compounds that can cause taste and odor problems in water.

EBMUD's Water Quality

The quality of EBMUD's water, assessed in terms of the five parameters described above, is remarkably high (Table 1). Both the characteristics of the District's water sources and the design of its treatment procedures contribute to this high quality.

In spite of all the technical knowledge in the field of water purification, there is no substitute for starting with a pure source. EBMUD's primary source, the upper Mokelumne River, is ideal in this respect. The District has rights to over 118 billion gallons of the Mokelumne's water per year (EBMUD, 1982a). The Mokelumne River watershed is a 1490 km^2 (575 mi^2) section of the Sierra Nevada covering portions of Alpine, Amador, and Calaveras counties. It is largely underlain by granite, a rock remarkably resistant to weathering (Santiago, 1983, pers. comm.). This helps to explain the low turbidity and TDS of the Mokelumne water. The cold climate and mountain environment account for the low level of organics. EBMUD owns its watershed lands and takes stringent precautions to protect them. Therefore, in addition to being both geologically and climatically ideal, the Mokelumne water is relatively free from civilization's impact.

	EBMUD[1]		SFWD[2]	STATE[3] HEALTH STANDARDS
TDS mg/l	ORINDA	60	95 (average)	500
	SAN PABLO	160		
SODIUM mg/l	ORINDA	2.0	3.9 - 8.0 (average)	--
	SAN PABLO	26		
TURBIDITY (NTU)	SUMMER	0.2 - 0.5	0.1 - 0.5[a]	1.0
	WINTER	0.5 - 1.0		
	SAN PABLO	0.1 - 0.2		
THMs g/l	AVERAGE	50	70.1[b]	100
	ORINDA	41		
BACTERIA	0		--	1/100 ml
VIRUS	0		--	--
TASTE AND ODOR	1 Odor Unit[c]		--	3 Odor Units

Table 1. Water Quality Values for EBMUD and SFWD with State Health Standards

Notes:

1) EBMUD, II, 1982; Yoo, 1983.
2) SFWD, 1982; SFWD, 1983.
3) EBMUD, III, 1982.

a) Values probably higher in 1982 due to higher rainfall.
b) Running average computed over past 4 quarters.
c) No detectable odor below one odor unit.

Every year about 37 gigaliters (10 billion gallons) of water flow into EBMUD's five local reservoirs from surrounding watersheds (see map, p. 111, EBMUD, 1982a). Although some is captured for system use, much is lost by evaporation and other reservoir losses. This is not a reliable source and accounts for roughly ten percent of EBMUD's total supply. The local water is not as pure as the Mokelumne source. Note the differences in TDS and sodium between the Orinda and San Pablo filter plants (Table 1). (Recall that the Orinda filter plant treats Mokelumne water and that the San Pablo filter plant treats water from San Pablo Reservoir.) A number of factors contribute to this. The local climate is warmer, the area is densely populated, and the underlying soil and rock in the San Pablo Reservoir watershed are more prone to weathering (Santiago, 1983, pers. comm.).

Though a pure source is essential to a high quality water supply, the role of treatment procedures is also very important. EBMUD employs a complex and well-coordinated purification system (Figure 1; Santiago, 1983, pers. comm.). The treatment of EBMUD's water begins in the reservoirs where copper sulfate and citric acid are added to control algae. After leaving the reservoirs, the water is treated with lime and chlorine. The lime is added to increase the pH and prevent corrosion of the pipes. Chlorine is added as a disinfectant. Next, the water is aerated, a process in which the water is spouted into the air by an array of fountains. Aeration is designed to remove THMs and odors and to saturate the water with oxygen. Then the water flows to a chamber where it undergoes three processes simultaneously--oxidation, adsorption, and coagulation. Oxidation removes manganese, adsorption removes organics, and both serve to remove taste and odor. Coagulation is a process in which alum, clay, and an experimental organic polymer are rapidly mixed into the water. In the next process, called flocculation, the alum and polymer coagulate into flake-like particles called floc. The floc, slowly mixed through the water, traps silt, clay, bacteria, and other small particles. The water then flows to sedimentation basins where the floc, along with all the material it had trapped, sinks to the bottom of the basins. Next, the water goes to rapid sand filters which filter out the remaining floc. After leaving the filters, the water undergoes further pH adjustment, fluoridation, and post-disinfection with chlorine. In pre-distribution storage, sodium or calcium hypochlorite is added for final disinfection.

Only water from the local reservoirs undergoes the full series of treatment processes. Water received from the aqueducts is already pure enough so as not to require full treatment (Santiago, 1983, pers. comm.). It undergoes filtration but not aeration, coagulation, oxidation, flocculation, and sedimentation.

There are a number of features of EBMUD's purification system which stand out (Santiago, 1983, pers. comm.). The first of these is EBMUD's clay feeder system. Directly before the flocculation process a special fine clay is added to the water to assist the alum and organic polymer in forming floc. The result is that the efficiency of the alum and polymer is increased.

EAST BAY MUNICIPAL UTILITY DISTRICT
WATER TREATMENT
PROCESSES AND CHEMICALS

FILTER PLANTS	
East of Hills	West of Hills
Lafayette Orinda Walnut Creek	San Pablo Sobrante Upper San Leandro Chabot (Standby only)

Treatment processes vary slightly between East and West of Hills plants due to differing water source characteristics.

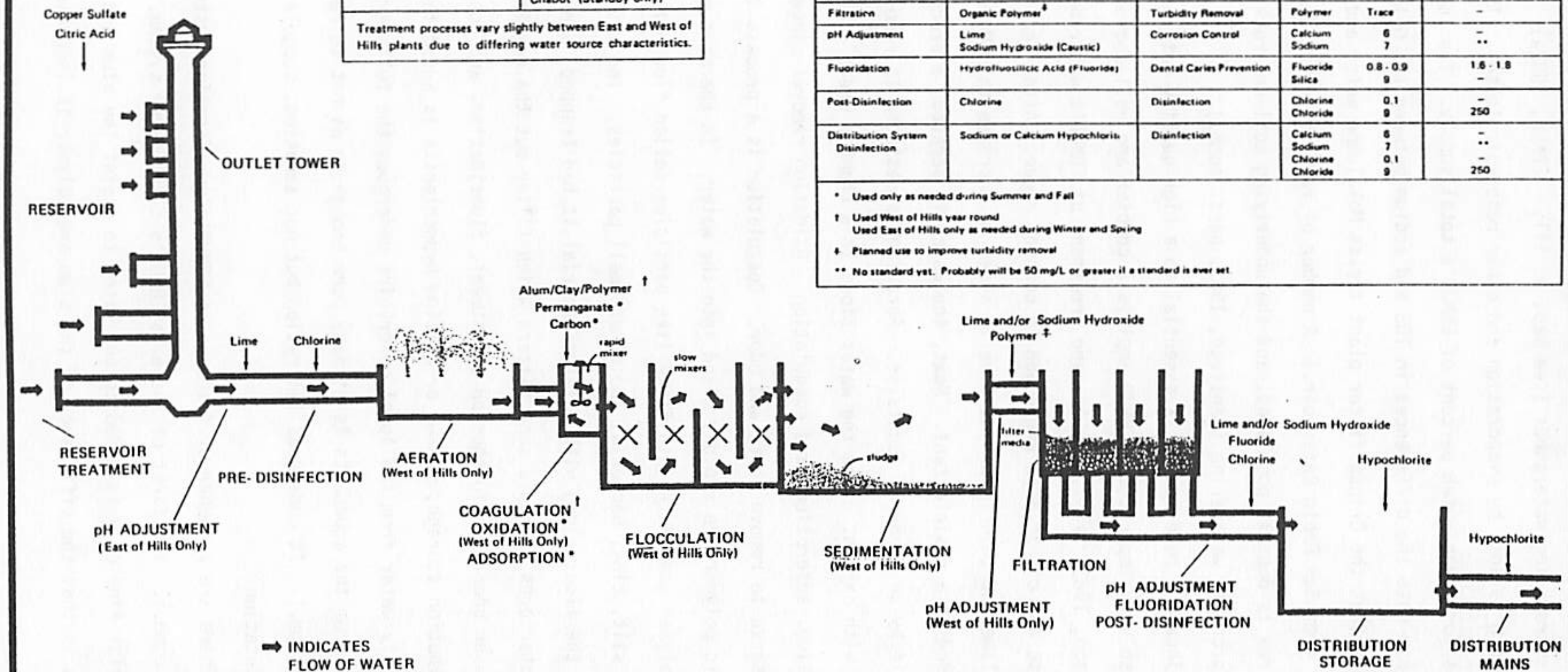
TREATMENT PROCESS	CHEMICALS	PURPOSE	AVERAGE RESIDUAL CHEMICAL IN TAP WATER mg/L (ppm)	DRINKING WATER STANDARD (MAXIMUM LEVEL) mg/L (ppm)
Reservoir Treatment*	Copper Sulfate Citric Acid	Algae Control	Copper less than 0.02 Sulfate 9 Citrate Trace	1.0 250 --
Pre-Disinfection	Chlorine	Disinfection	Chlorine 0.1 Chloride 9	– 250
Aeration (West of Hills Only)	None	Odor Removal Oxygen Saturation		
Oxidation* (West of Hills Only)	Potassium Permanganate	Manganese Removal Taste & Odor Removal	Potassium 0.8 Manganese 0.005	– 0.05
Adsorption*	Powdered Activated Carbon	Taste & Odor Removal Organics Removal	Carbon Trace	–
Coagulation †	Aluminum Sulfate (Alum) Organic Polymer ‡ Clay ‡	Turbidity Removal	Aluminum 0.1 Sulfate 9 Polymer Trace	– 250 –
Flocculation (West of Hills Only)	None	Turbidity Removal		
Sedimentation (West of Hills Only)	None	Turbidity Removal		
Filtration	Organic Polymer‡	Turbidity Removal	Polymer Trace	–
pH Adjustment	Lime Sodium Hydroxide (Caustic)	Corrosion Control	Calcium 6 Sodium 7	– **
Fluoridation	Hydrofluosilicic Acid (Fluoride)	Dental Caries Prevention	Fluoride 0.8 - 0.9 Silica 9	1.6 - 1.8 –
Post-Disinfection	Chlorine	Disinfection	Chlorine 0.1 Chloride 9	– 250
Distribution System Disinfection	Sodium or Calcium Hypochlorite	Disinfection	Calcium 6 Sodium 7 Chlorine 0.1 Chloride 9	– ** – 250

* Used only as needed during Summer and Fall

† Used West of Hills year round
Used East of Hills only as needed during Winter and Spring

‡ Planned use to improve turbidity removal

** No standard yet. Probably will be 50 mg/L or greater if a standard is ever set.



WATER QUALITY DIVISION 6/80
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Source: EBMUD Water Quality Division, 1980

Fig 1. EBMUD Water Treatment System

Another feature is the organic polymer itself (EBMUD, 1982a). It is being used on an experimental basis at three of EBMUD's filter plants. The polymer is a special new coagulant which reduces the amount of alum needed, thereby reducing costs and chemical waste.

Although THMs are already at a low level in its waters, EBMUD is undertaking efforts to reduce them further (EBMUD, 1982a). It is known that chlorine reacting with naturally-occurring organic matter in water can create THMs. To combat this, EBMUD is constructing a chlorine injection station at a point midway between Pardee Reservoir and the East Bay. This station, due to be completed in 1983, will provide a "booster treatment" which will reduce the amount of chlorine that must be administered to water leaving Pardee. Breaking the chlorination process into two stages reduces the total amount of chlorine which must be used, thereby reducing the formation of THMs. Another experimental procedure aimed at reducing THMs is occurring at the San Leandro filter plant. This procedure combines chlorine and ammonia to form chloramines. The chloramines are then used in the place of chlorine as the disinfectant.

Although asbestos suspended in drinking water has not been proven to be dangerous, EBMUD monitors the substance carefully and keeps its levels as low as possible (EBMUD, 1982a). A study of EBMUD water done at the University of California revealed that asbestos levels in EBMUD water are among the lowest in the Bay Area. The California Department of Health Services has recommended that all agencies supplying drinking water use the same filtration system used by EBMUD to minimize asbestos levels.

Comparison of the EBMUD and SFWD Systems

A comparison of the EBMUD and SFWD systems is an excellent method of informally assessing the EBMUD system (Table 1). The two systems are similar in many ways. SFWD's water source is the Tuolumne River in Yosemite National Park (SFWD, b, n.d.). The Hetch Hetchy watershed covers 459 mi^2 sloping west from the crest of the Sierra. The granite watershed is largely without soil or vegetation and is very similar to the Mokelumne watershed, though it is in a park and more heavily used. After being stored in Hetch Hetchy Reservoir, SFWD water travels to San Francisco via the 148-mile Hetch Hetchy aqueduct. Once the water is in the San Francisco area, it either flows directly into the distribution system or is stored in one of SFWD's local reservoirs.

A comparison of the treatment techniques employed by EBMUD and SFWD reveals the following differences: First, SFWD does not filter the water it receives from Hetch Hetchy Reservoir (SFWD, b, n.d.). The only treatment this water undergoes is the addition of lime to control corrosion, chlorination, and fluoridation. Second, although water from SFWD's local reservoirs is treated at one of the Water Department's filter plants, the treatment is not quite as extensive as EBMUD's treatment of its local water (SFWD, a, n.d.). Specifically, aeration and oxidation (with potassium permanganate) are not employed.

The San Francisco Water Department maintains that the water received from its Hetch Hetchy Reservoir does not require filtration because the water remains very clear throughout the year (SFWD, b, n.d.). The latest turbidity measurement of SFWD's mountain water (treated with lime and chlorine) supports this (SFWD, 1982). The turbidity was measured at 0.2 NTU (Table 1).

It is interesting to note that SFWD water is significantly higher in THMs than EBMUD's water. Perhaps if the water were aerated, this would not be true. Furthermore, SFWD water is significantly higher in manganese as well. SFWD values range from 0.004 to 0.01 mg per liter (SFWD, 1982). The values are 0.002 or less at all EBMUD filter plants except Sobrante and San Pablo, where it is 0.007 mg per liter (EBMUD, 1982b). EBMUD employs a technique to remove manganese and SFWD does not.

Portecting EBMUD's Water Quality in the Future

Sooner or later the demand for EBMUD's water will outgrow its present supply. In anticipation of this, EBMUD personnel are closely examining all the District's options so that it may successfully meet the demands of the future without compromising on quality.

Right now, EBMUD has rights to 1230 megaliters (325 million gallons) per day of water from the Mokelumne River and rights to divert approximately 507 megaliters (134 million gallons) per day from the American River via the Folsom-South Canal (EBMUD, 1982). However, in light of the 1976-77 drought, the safe yield--the maximum yield available under the most extreme circumstances--of the Mokelumne source is only 655 megaliters (173 million gallons) per day. Present demand is around 757 megaliters (200 million gallons) per day.

The relatively low safe yield of the Mokelumne source and the projected increase in demand for EBMUD water (close to 250 million gallons per day by the year 2000) has prompted EBMUD to look into various possibilities for a supplemental water source. A study, done in conjunction with CCWD, of the costs and qualities of five possible sources was begun in October of 1981 (EBMUD, 1982). The five possibilities are the expansion of Pardee Reservoir (EBMUD's present source), the Sacramento River near Hood, Clifton Court in the Southern Delta, Bixler in the Western Delta, and the American River at the Folsom-South Canal. It is known that the quality of Delta water is inferior to water from the American River (EBMUD, 1982). It is especially high in chlorides and minerals, two conditions which drive up the cost of treating water.

In EBMUD's evaluation, the quality of supplemental sources is only important in how it affects the quality of the water which reaches EBMUD's customers (EBMUD, 1982c). Two factors are important here, and the first is blending. The supplemental source may be blended with Pardee water in an effort to render the lower quality of the supplemental water insignificant. The second factor is local reservoir storage. When Pardee water is stored in one of EBMUD's terminal storage reservoirs, its TDS increases. The same effect is expected if water from a supplemental source is stored in the terminal reservoirs. This phenomenon could tend to mask any quality differences between Pardee water and a supplemental source. All five of the possible sources are presently being studied in terms of both of these factors.

Another possible development which might affect the quality of EBMUD's water is the proposed merger with the Contra Costa Water District (Santiago, 1983, pers. comm.). A year-long study, due to begin in June, is being prepared by EBMUD and CCWD to examine a variety of possible arrangements with CCWD, ranging from leasing them water when it is available to a full merger. Quality implications will be a major theme of this study.

A master design for EBMUD's future is being prepared at the order of EBMUD's Board of Directors (EBMUD, 1982a). This Water Action Plan is due in mid-1984 and is being reviewed by a citizens advisory committee. The major themes of the Water Action Plan are water quality, water supply, conservation, and security.

Despite the hard decisions ahead, EBMUD emphasizes its commitment to water quality (EBMUD, 1982a). District planners are convinced that the successful implementation of a plan that delicately combines the development of new sources with careful treatment and water conservation can maintain or even improve the District's present water quality.

Conclusion

The purity of the Mokelumne's water is the foundation of EBMUD's extraordinary water. This foundation is unquestionably improved on by means of a finely-tuned purification system, but it would not be the same without the mountain water, as the differences in TDS and sodium between Orinda and San Pablo filter plants show (Table 1). EBMUD's treatment system is not really equipped to remove dissolved solids. It is expensive to do and was wisely avoided when EBMUD acquired the Mokelumne source, which is naturally very low in dissolved solids.

The similarities between EBMUD and SFWD provided for an effective and revealing comparison. The excellence of both the Mokelumne and the Tuolumne sources assures high quality water to both systems, but the extra steps EBMUD takes in its purification system apparently do make a difference.

Overall, EBMUD does an impressive job. The water purification system is sophisticated, and experiments aimed at improving it further are underway. The Water Action Plan is a project of impressive magnitude which seriously and methodically addresses the hard questions of the future.

It is true that pure sources of water exist. It is also true that efficient and capable agencies, like EBMUD, are purifying and distributing water from these sources. But, there are also sources of water now in use which are not so pure. CCWD's Delta source is an example. There are people in this state who do not have access to quality water, and the problem could get worse. The intensity of water politics has increased dramatically in the last ten years. Demand steadily rises. Does someone have to lose?

When I look at the astounding decline in water consumption during the 1976-77 drought, the answer seems plain. The sacrifice was minimal and the achievements could be great. If people conserved the way they did then, new sources would not have to be sought so quickly, and EBMUD could serve more people. Whether people can really conserve without the presence of an immediate crisis remains to be seen. It will be interesting to see what role conservation plays in EBMUD's Water ACtion Plan.

The old American ideal of quality and quantity going hand in hand is fading fast. In a time when even EBMUD is considering future sources of low quality, conservation must play an active role to assure the widespread availability of quality water in the future. In a crowded and strained world, no other way is possible.

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