Key Distinguishing Characteristics

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Selection of a
CALFED Bay-Delta Program Draft Preferred Alternative
Implications for Drinking Water

January 8, 1998

Summary

Most Californians get their drinking water supplies from the Sacramento-San Joaquin Delta. The choice of a Delta alternative has important implications for the drinking water supply to these citizens. Water taken from the Delta is treated to destroy disease causing organisms, the agents in drinking water presenting the greatest health threat to people. While drinking water produced from the Delta supply is generally safe to drink, it is also true that treatment is not an absolute guarantee that all organisms having the potential to cause disease are destroyed. For this reason, it is important to establish an additional barrier to disease by protecting drinking water sources from contamination. In its current configuration, the Delta is a relatively unprotected drinking water source.

The desire to increase the safety of drinking water has resulted in federal and state legislation requiring higher treatment efficiency, including more rigorous disinfection. An unfortunate side effect of disinfection is formation of unwanted chemical byproducts, some of which are suspected to cause cancer over a lifetime of water consumption. More rigorous disinfection has the tendency to increase formation of these unwanted byproducts. The challenge, therefore, is to produce a highly disinfected drinking water while minimizing unwanted byproducts.

Two features of Delta water quality complicate attainment of the optimum balance of strong disinfection and byproduct suppression. Bromide, a salt of sea water origin, is present in Delta water supplies as a result of intrusion into the Delta of sea water. The soils of Delta islands are important sources of organic carbon resulting from natural decomposition of plant materials. Together, bromide and organic carbon react with disinfectant chemicals to produce a broader range and higher concentrations of chemical disinfection byproducts than is true for drinking water sources lower in these two constituents. As a result, municipalities using Delta waters are at a relative disadvantage with respect to the cost and complexity of producing safe drinking water.

Alternative 1 would not significantly improve source water protection, nor significantly decrease bromide concentrations in drinking water supplies taken from the Delta. Alternative 2 would provide modestly increased protection of the supply while reducing bromide concentrations of drinking water supplies on the order of 40% for Contra Costa Water District and about 25% for South Delta (SWP & CVP) exports. Organic carbon concentrations for Alternatives 1 and 2 might be reduced as a result of planned source control activities, although the feasibility of this has not been established. Alternative 3 would effectively protect the drinking water supply from adverse Delta influences. This alternative would also reduce bromide concentrations about 6-

fold, as compared to the predicted future condition if no alternative is implemented. Alternative 3 is expected to effectively reduce the influence of organic carbon generated in the Delta.

The need to provide the greatest feasible protection of Delta drinking water supplies and the need to provide high level disinfection while suppressing formation of harmful byproducts are issues that must be among the important considerations leading to selection of a Delta solution.

Populations Receiving Drinking Water From the Delta

The majority of Californians (well over 20 million) drink water that comes from the Sacramento-San Joaquin Delta. The State Water Project serves most of the people in Southern California South of the Tehachapi Mountains. In addition, municipalities in Solano, Napa, Santa Clara, and Fresno Counties are served by the SWP, while drinking water customers in Contra Costa County are served from the federal Central Valley Project. These service areas are depicted on Figure 1. The selection of a Draft Preferred Alterative has important implications for drinking water uses, and is the subject of this paper.

Water Treatment

Waterborne diseases such as cholera have caused the deaths of untold numbers of human beings, and continue to do so in many parts of the world. At about the turn of the century it was discovered that addition of chlorine to drinking water is effective in destroying disease causing organisms, and it has been used very effectively in this country since then. Disinfection of drinking water by chlorine has saved countless lives, and continues to protect people today.

The most important objective of treating drinking water is to render it free of infective agents such as bacteria, protozoa and viruses. Source waters taken from the Delta are subjected to treatment which basically includes removal of particulate matter, along with disinfection. The processes are closely linked because particle removal greatly increases the effectiveness of disinfection. The process of removing particulate matter generally involves mixing coagulant chemicals with the source water, which causes the particulates to aggregate and to settle out. The settled water is then filtered, usually through beds of special sand mixtures. At one or more points in the process, disinfectant chemicals are applied. Water that flows from the treatment facility into the pipes that distribute the water to homes and businesses contains a sufficient disinfectant residual to prevent growth of harmful bacteria or other organisms in the distribution system, up to the taps of customers.

Application of these processes to treat waters from the Sacramento-San Joaquin Delta has resulted in good quality drinking water that generally meets all currently applicable drinking water standards. The safety of citizens consuming waters of Delta origin is the constant concern of the staff of the Department of Health Services, the agency having regulatory responsibility for California drinking water municipalities treating and serving the water. Safe drinking water is also the primary concern of the scientists, engineers and technicians of the water purveying entities who vigilantly manage these systems.

Source Water Protection

A basic principle of producing safe, palatable, and affordable drinking water is to take water from the best reasonably available source. The reason source water protection is important in drinking water production is that treatment by itself does not always guarantee safe drinking water. When treatment processes are functioning normally, they remove a high percentage of the particulate matter in the water, including a high proportion of the pathogenic organisms that may have been present in the source water. Subsequent disinfection ensures an additional high percentage removal or inactivation of most disease causing organisms. As an additional benefit, the coagulation/sedimentation/filtration processes remove significant percentages of dissolved materials present in the water, including metals, synthetic organic substances (such as some pesticides), and organic carbon. However, treatment processes can fail and even when functioning normally cannot guarantee that all undesirable constituents are removed. In addition, efforts to remove pathogens can leave undesirable chemical residues in the treated water. Preventing pollution by source control provides an important additional barrier to waterborne disease, and is increasingly seen as a necessary component of a comprehensive system to deliver safe drinking water.

The key to predicting the effectiveness of treatment is to accurately predict how much of an undesirable substance or organism may be present in the source water, assess what percentage removal (or pathogen inactivation) is provided by the treatment process, then determine whether any remaining concentration of a chemical or number of live organisms will consistently meet the standards for safe drinking water. Lengthy experience has enabled accurate prediction of the beneficial effects of treatment. For example, a certain combination of particulate removal and disinfection processes will result in a 99.99 percent removal or inactivation of pathogens, when processes are operating properly. The big uncertainty lies in predicting the concentration of pathogens in the source water, because it is possible for the number of pathogenic organisms in the source water to be sufficiently large that even high percentage removals in the treatment process still leaves enough surviving pathogens to make people sick. The less source waters are protected the greater the uncertainty in predicting source water concentrations of pathogens and other agents and, thus, the lower the barrier to waterborne disease.

In recent years, citizens of Milwaukee and Las Vegas experienced illness and deaths due to the presence of the protozoan pathogen *Cryptosporidium parvum* in their drinking water. In both cases it is believed the treatment processes were functioning normally, but that the processes were overwhelmed by very large *Cryptosporidium* concentrations in their source waters. This experience is being taken seriously by the drinking water regulators and industry because there is no effective treatment for cryptosporidiosis. After protracted illness lasting up to weeks, normally healthy persons usually recover spontaneously. However, the disease can be deadly to persons having weak immune systems, such as AIDS, cancer, and transplant patients. *Cryptosporidium* is particularly dangerous as compared to other pathogenic organisms because it uses a protective cyst to resist chemical destruction; and, other disease causing organisms such as *Giardia lamblia* have similar capabilities. The ability of some organisms to effectively resist

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destruction by disinfectants places greater dependence on minimizing source water concentrations of pathogens, and on highly effective filtration.

The discovery of organisms such as *Cryptosporidium* that are highly resistant to disinfection has stimulated the U.S. Environmental Protection Agency to establish the Surface Water Treatment Rule that requires more rigorous disinfection than was previously required. An Enhanced Surface Water Treatment Rule is also anticipated, which is intended to further improve overall quality of disinfection in the nations's drinking waters. As we shall see, these new rules have great significance for Delta water supplies, and important implications for selection of a Delta Alternative.

In addition to the benefits of providing predictable pathogen and pollutant concentrations in source waters, protected sources of drinking water are also desirable as insurance against process failure. Filters do not always operate at optimum efficiency, and sometimes they fail. Disinfectant doses can be in error due to mechanical malfunction. Even though modern, well equipped, and well operated plants have redundant features and instruments to help ensure against process failure, a treatment facility can be thought of as handling the flow of a small river; not all treated gallons can be equal with respect to treatment quality. This is especially the case when source water quality is highly variable. High variability of water turbidity, for example, necessitates changes in the treatment process. During transitional periods, until treatment processes can be "tuned" to reflect changes in source water quality, there is a higher probability of producing lesser quality drinking water.

Hundreds of thousands of synthetic organic chemicals are used in California. Many of these can find their way to the Delta through various forms of discharges including accidental or intentional spills. While treatment can effectively remove many of these compounds, it is also known that some are not effectively removed by typical treatment processes. This presents a degree of risk that, though not quantified, is generally small. Testing by agencies treating Delta waters have rarely detected chemical pollutants in treated drinking water, excepting compounds that are a result of the treatment process itself. (Disinfection byproducts are discussed later in this paper.) Small risk or not, it would be desirable to reduce the exposure of Delta drinking water supplies to chemical pollution.

To ensure against treatment processes being overwhelmed by unpredictable high concentrations of harmful agents in the source water; to ensure against treatment process failure; to provide for a more uniform source water quality; and, to avoid the risk of harmful chemical residues surviving the treatment process, water purveyors understandably prefer maximum protection of their source water supplies. The ideal formula is for a drinking water agency to acquire a mountain source of water supply, and to gain control over the entire watershed so that any land use within the watershed is compatible with maintaining the quality of the water supply. This formula is followed by municipalities in California and throughout the nation, and has proven successful. Examples include Seattle, Portland, Anchorage, Boston, and San Francisco.

As precipitation from upstream watersheds moves through stream channels toward the Bay-Delta and ocean, it naturally picks up minerals, especially salt, from the watershed. In addition, source waters are affected by waste discharges resulting from animal and human activity. Included in such discharges can be salts, sediments, petroleum, pesticides, household and industrial chemicals, heavy metals, drug residues, animal manure, human organic waste and especially pathogens (bacteria, viruses, protozoa) that come from storm water runoff, and from agricultural, municipal and industrial discharges, from boats and other recreational uses of Delta waters, and from atmospheric deposition. Also, in the Sacramento-San Joaquin Delta, bromides, (salts of sea water origin) are present as a result of sea water intrusion; and, naturally occurring organic carbon compounds are discharged into Delta source waters from the peat islands of the Delta. Bromide and organic carbon have particular significance to Delta drinking water supplies, as shall be discussed later.

Ranking of Alternatives With Respect to Source Water Protection
Compared to a protected mountain watershed, the Delta is a relatively poor source of drinking water. Experts believe drinking water produced from Delta exports is safe, but the margin of safety can definitely be increased if the source water were better protected. Compared to Alternative 1 (minimal physical changes to the Delta), Alternative 2 (through-Delta system) should more effectively convey Sacramento River water through the Delta and should, therefore, somewhat improve source water protection. Alternative 3 would bring Sacramento River water more directly to drinking water producers and would significantly protect the drinking water source from Delta influences. (Sacramento River water is much better quality than is found in the Delta, and is subject to fewer negative influences.) However, Alternative 3 would still not provide the ideal formula as described above, because although better protected, the Sacramento River watershed is not completely protected from pollution.

One requirement of the Delta decision process is to determine the importance of improved source water protection, taking into account the many other considerations that must go into the decision.

Disinfection Byproducts
The discussion that follows should be considered within the context that the most important facet of water treatment is disinfection, and unwanted byproducts of this process (produced by chemical reaction of the disinfectant with other constituents in the water) are unlikely ever to have the health consequences of inadequate disinfection.

Chlorine kills pathogens because it is a powerful chemical oxidant that can destroy or disrupt organic molecules. As analytical techniques improved in the early 1970's, scientists began to understand that the very reactivity that enables chlorine to be so effective against disease organisms also causes chlorine to react with other substances in water to form chlorinated byproducts, including chloroform. (Chloroform consists of three chlorine atoms connected to one carbon and one hydrogen molecule. Chloroform production requires chlorine and a source of organic carbon which, in surface waters, typically comes from naturally occurring organic byproducts of plant decomposition). During this period it was also discovered that, in the presence of bromide, a salt that is present in sea water, chlorine and organic carbon can react to form combinations of one carbon, one hydrogen and combinations of chlorine and bromine atoms totaling three. Collectively these chemicals are termed **trihalomethanes (THMs)**. The trihalomethanes found in drinking water treated by chlorine are chloroform ($CHCl_3$), bromodichloromethane ($CHBrCl_2$), dibromochloromethane ($CHBr_2Cl$), and bromoform ($CHBr_3$).

Animal testing data indicated chloroform has the potential to cause cancer over a lifetime of exposure; so, in 1981, drinking water regulations were established for trihalomethanes. According to this regulation, all four species of THMs taken together must not exceed 100 ug/L (parts per billion) in treated drinking water supplied to customers.

The Sacramento-San Joaquin Delta is connected to San Francisco Bay and the Pacific Ocean, and is subject to tidal influence. As a result, concentrations of bromide in Delta export waters resulting from sea water intrusion are higher than in 95 percent of the source waters of the nation. In its natural condition, the Delta was a maze of meandering channels passing through wetlands of bulrush, cattails and similar marsh plants that, over time, deposited organic residues up to 60 feet deep. During the gold rush period, islands were constructed by building levees and the rich peat soils were used to support an agricultural industry that was important then, and is still important to California.

Shortly after the proposed THM regulation was proposed, water purveyors began evaluating Delta source waters and determined that discharges from Delta peat islands are a significant source of organic carbon contributions to waters exported from the Delta. Subsequent investigation resulted in the estimate that, during Water Year 1988, island drainage contributed 40 to 45 percent of the organic carbon in the Delta during the irrigation months (April to August), and 38 to 52 percent during the period November through February when discharges were made to leach (remove) salts from island soils.[Ref]. As a result of these discharges and other local sources, organic carbon concentrations in South Delta exports average about 4 mg/L (parts per million), whereas concentrations in the lower Sacramento River average about 2 mg/L. [Ref]

Taken together, the presence in Delta exports of bromide from the sea water connection and elevated organic carbon from Delta sources presented purveyors of drinking water from the Delta with a significant challenge in meeting the THM regulation. Most agencies treating water from the Delta were unable to meet the regulation without changes in their treatment practices. However, the process changes adopted were generally successful in meeting the regulation, and with acceptable cost consequences. One of the most common changes was to discontinue the use of chlorine to maintain disinfectant residuals in distribution systems and, instead, substitute chloramine which, though a weaker disinfectant, prevents production of THMs in distribution systems on the way to customers' taps. The challenge has always been to maintain adequate disinfection while minimizing unwanted chemical byproducts.

It is axiomatic in drinking water treatment that no benefit is without consequence. There has been some question as to whether chloramine is a sufficiently strong to adequately maintain disinfection in distribution systems. Also, chloramine is toxic to aquarium fish and interferes with kidney dialysis. Because of the limited experience using chloramine, its health implications are not yet fully understood, even though it now appears to be safe for this use.

The U.S. Environmental Protection Agency has announced its intention to adopt a more stringent drinking water rule for disinfection byproducts. The new rule, planned in two stages, is called the Disinfectants/Disinfection Byproducts Rule. Stage I of the rule will reduce allowable THM concentrations from 100 ug/L (parts per billion) to 80 ug/L. In addition, new criteria are proposed for five haloacetic acids (60ug/L total), bromate (10 ug/L), and Total Organic Carbon (2 mg/L), (which is about the TOC concentration present in the lower Sacramento River). The haloacetic acids and bromate are chemical byproducts of disinfection that have more recently been associated with health concerns. Agencies treating source water exceeding 2 mg/L organic carbon must undertake studies to determine how to reduce organic carbon concentrations through improved treatment.

EPA has also announced an intention to consider more stringent disinfection byproduct regulations in a Phase II of the D/DBP rule making process. The initial suggestion is to reduce allowable THMs to 40 ug/L. The timing of the Phase II rule is not certain, but should be considered within the next few years.

The facilities to treat water for more than 20 million California citizens involve very large capital investments, and this fact requires water purveyors to plan carefully for the future. Because the Delta as currently configured presents water quality challenges due to bromide and organic carbon, water agencies have generally concluded that expected new drinking water regulations for disinfection and for disinfection byproduct control probably cannot be met using chlorine. Accordingly, many are planning to convert to use of ozone for disinfection.

Ozone is a very powerful disinfectant which is able to destroy some pathogens that even chlorine does not consistently kill. This feature increases insurance against filtration failures and high pathogen concentrations in the source water. Ozone does not produce chlorinated byproducts such as chloroform and the other chloro-bromo THMs. Therefore, ozone use should enable lower THM standards to be more easily met. Ozone has an important additional advantage in that it is very effective in controlling adverse taste and odor that is frequently associated with algal growths in source waters.

However, ozone is expensive. In addition, it does not have a persistent disinfection capacity so other compounds, such as chloramine, must be used to protect distribution systems from pathogen growth. The strong oxidative capacity of ozone breaks complex organic molecules into simple compounds that provide readily usable nutrition for pathogens and other organisms. As was mentioned earlier, chloramine is a relatively weak disinfectant and there is some question as to how effectively it can prevent pathogen growth in distribution systems being provided with a readily usable nutrition source resulting from ozone use.

Finally, ozone produces chemical byproducts of its own. In the presence of bromide, ozone produces both bromoform ($CHBr_3$) and bromate (BrO_3^-). Bromoform will be regulated within the THM regulation of the proposed Phase I Disinfectants/Disinfection Byproducts Rule, and bromate will also be regulated because it appears to have a significant cancer causing potential of its own. Apart from these compounds, ozone has the capacity to produce a number (perhaps a large number) of exotic chemical byproducts. The presence in the source water of bromide multiplies the numbers of chemical byproducts that could be produced by use of ozone. There is a probability that future investigation will determine other disinfection byproducts present health implications and need to be excluding from drinking water. Reducing the availability of chemical "building blocks" in the form of bromide and organic carbon will reduce the probability that investments in new water treatment technology would be degraded because of future identification of new byproducts of concern.

Other treatment processes, such as granular activated carbon treatment, ultrafiltration, and reverse osmosis exist, and could address most of the byproducts of treatment alternatives. Such processes can, however, be prohibitively expensive.

We have learned that the presence of bromide and organic carbon in Delta source waters present unusual treatment challenges to drinking water purveyors. Because national drinking water regulations are based on the country as a whole, there is concern that Californians may be at a disadvantage in meeting these regulations, given the relatively poor quality of Delta source waters. Clearly it would provide improved certainty in planning safe drinking water supplies if Delta source waters could be improved.

Ranking of Alternatives with respect to Disinfection Byproduct Control

Bromide
Alternative 1 would result in no significant reduction of bromide concentrations of export waters. Alternative 2 would significantly reduce bromide concentrations (on the order of 40 %) in waters taken by Contra Costa Water District, and would reduce concentrations at the State Water Project export in the South Delta on the order of 25 percent. A dual transfer facility of 10,000 cfs plus or minus 2,000 cfs as proposed, would result in a 6-fold reduction of bromide in waters supplied to municipalities throughout the South Bay, Central Valley and Southern California. The dual transfer option would not result in significant bromide reductions for Contra Costa Water District. To extend this benefit to the agency would require connection to the dual transfer facility. Figure 2 and Figure 3 present estimated bromide concentrations at Contra Costa Water District's intake and at the SWP intake (Clifton Court), respectively, that would result from implementing the alternatives.

Organic Carbon
With Alternatives 1 and 2, measures would be undertaken to reduce discharges of organic

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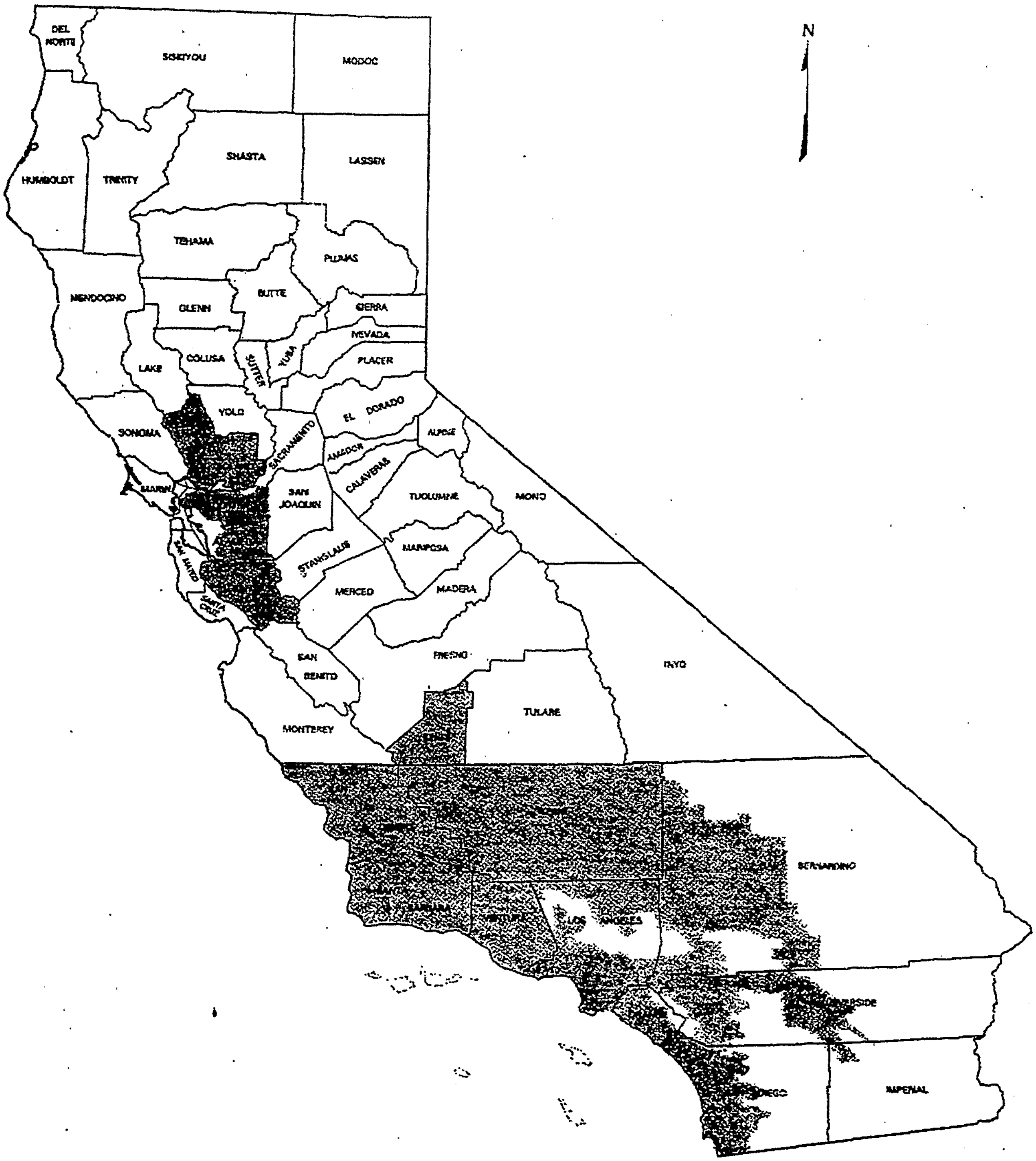
Figure 1. Population Areas in California Served Drinking Water from Sacramento-San Joaquin



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Predicted Bromide at Rock Slough

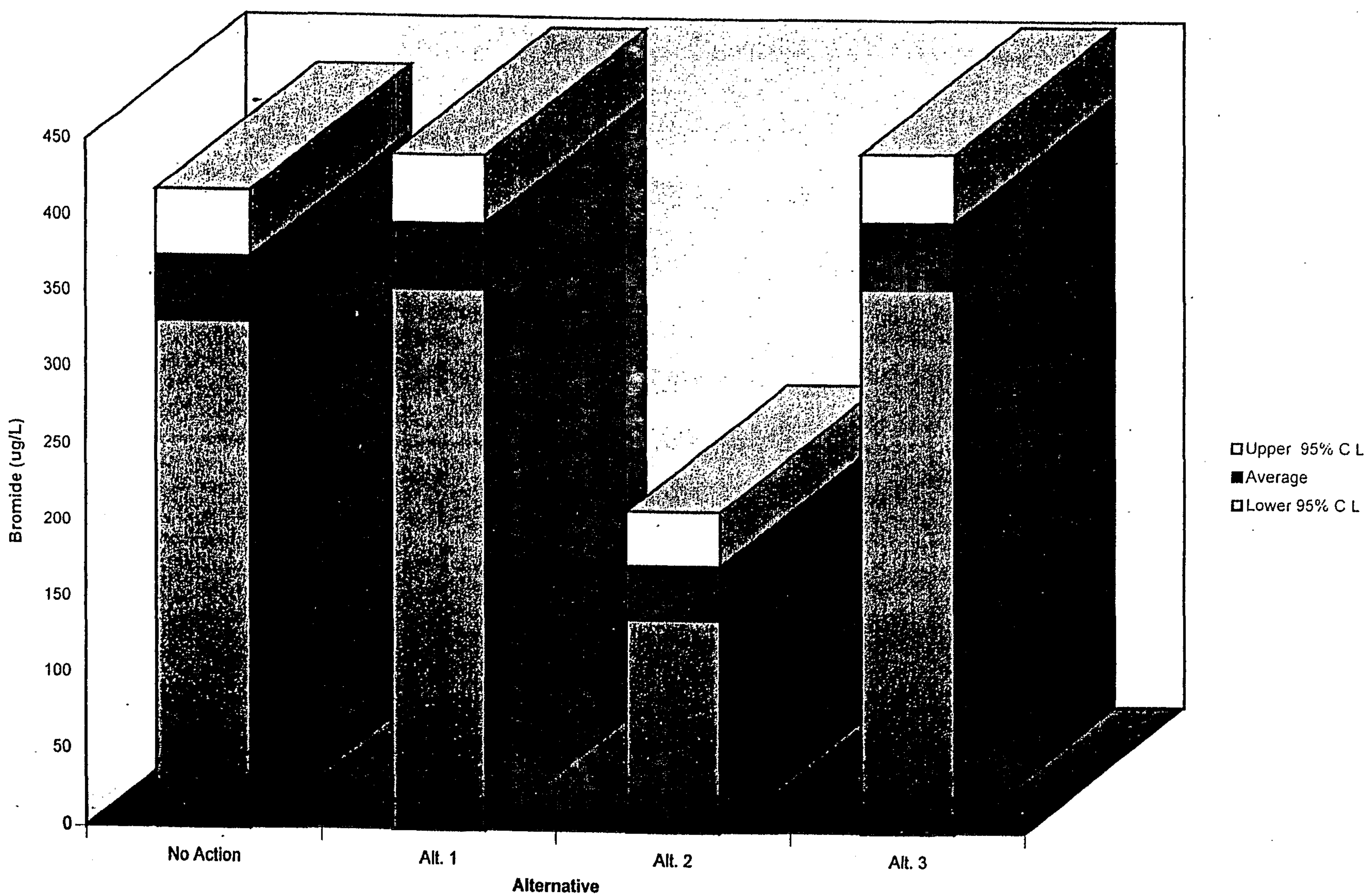

FIGURE 2

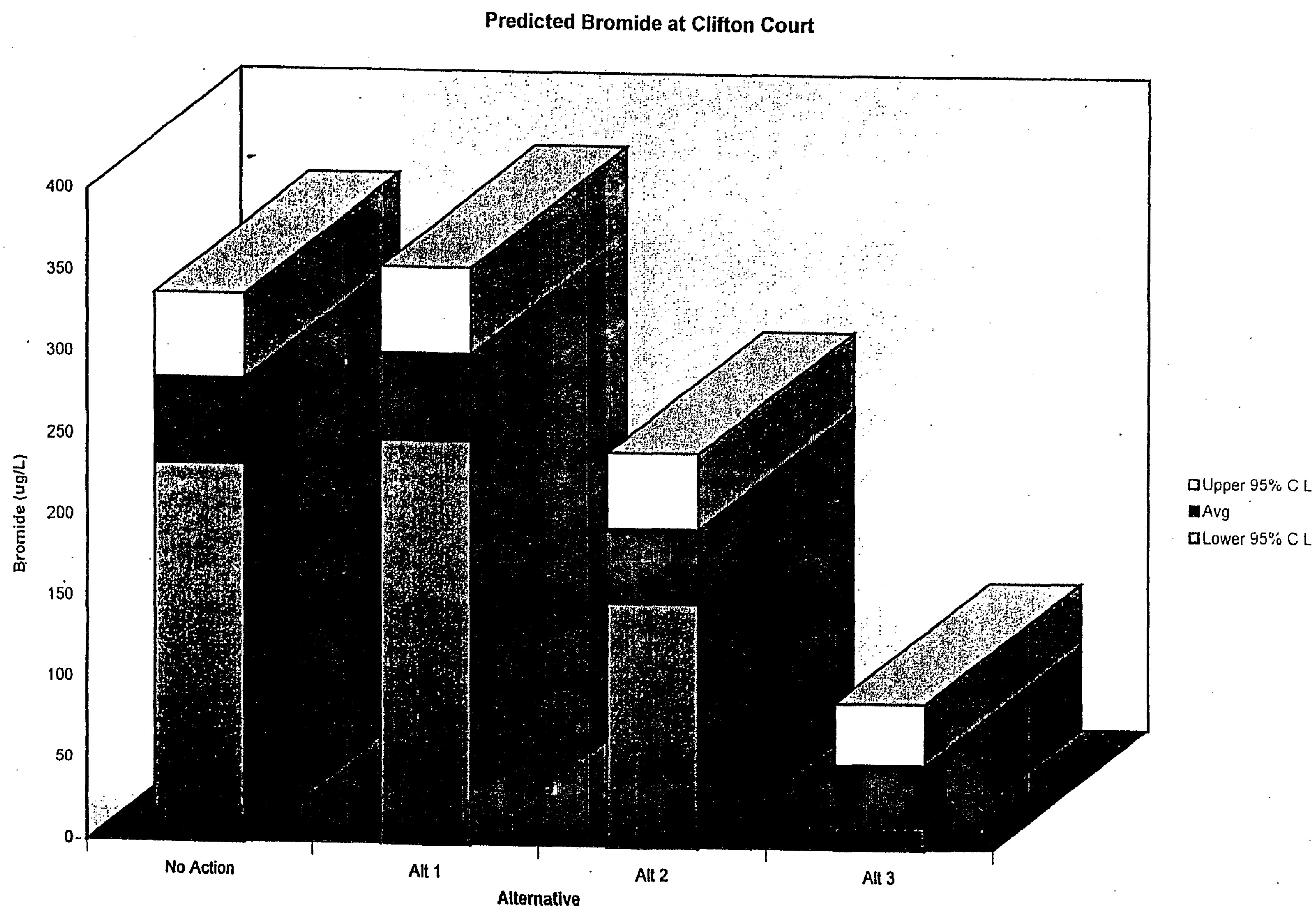

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FIGURE 3

carbon from Delta islands into drinking water supplies. It is difficult to predict how effective these measures would be, as the feasibility of reducing these discharges has not been established. Alternative 3 would greatly reduce the influence of organic carbon sources in the Delta. Compared to bromide, organic carbon is a somewhat more tractable problem, as it is possible to reduce concentrations to some extent through existing treatment processes. Bromide cannot be similarly removed.

Conflict between Disinfection and Disinfection Byproduct Control - Implications for the Delta

On one hand, the current regulatory trend is toward more rigorous disinfection of drinking water to protect people from disease causing organisms such as *Cryptosporidium*. On the other, increased awareness of potential health effects of a range of unwanted disinfection byproducts is driving increasingly stringent regulations to control them. There is an inherent tradeoff between these regulatory directions because stronger disinfection will tend to create more unwanted chemical byproducts. The entire nation is subject to these new rules, so water purveyors throughout the country will be grappling with these conflicting objectives. However, the presence of elevated organic carbon and bromides in Delta waters will present special challenges to those who use Delta waters. Selection of a Delta alternative will, therefore, have a great effect on the future of drinking water supply in California and, consequently, will directly affect the citizens who receive their drinking water from the Delta. This is true not only from the perspective of public health protection, but also of cost, as citizens are the ultimate source of the funds to be invested.

Overall Considerations

Selection of a Delta alternative will have important drinking water consequences. The choice among alternatives will determine the degree to which Delta drinking water sources are protected from pollution, especially from pathogens that have the potential to cause waterborne disease. Better protected source water will increase the overall safety of the drinking water supply. Reduction in bromide and organic carbon in export waters will help reduce the tendency to produce unwanted chemical disinfection byproducts, will reduce the technical complexity of controlling these byproducts, and will decrease the cost of meeting drinking water regulations. Reductions in bromide and organic carbon will also reduce the possibility of future requirements for control of as yet unknown disinfection byproducts.

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