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Health Consultation

Perchlorate Contamination in the Mather Air Force Base Water Service Area

AEROJET GENERAL CORPORATION

RANCHO CORDOVA, SACRAMENTO COUNTY, CALIFORNIA

CERCLIS NO. CAD980358832

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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Prepared by:

California Department of Health Services
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

BACKGROUND AND STATEMENT OF ISSUE

The California Department of Health Services (CDHS), under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), is conducting public health assessment activities on the Aerojet-General Corporation (Aerojet) Superfund site in Sacramento County, California (See Figure 1, in attachments). A preliminary public health assessment written in December 1988 recommended that when additional environmental information and data became available ATSDR would make another assessment (1). A site review and update written in March 1993 also recommended a public health assessment be conducted when more data became available (2).

This health consultation is one in a series that will be performed as part of the ATSDR public health assessment process at this site. During this process, data and information on the release of hazardous substances and their impact on public health will be evaluated. Four health consultations have recently been written as part of this series (3-6). In this health consultation, we will focus on describing the perchlorate contamination that has reached the Mather Air Force Base Water Service (Figure 1) and evaluate the health impact from the exposure that has occurred. We are also in the process of writing several other health consultations that focus on perchlorate exposure to consumers of water from other water purveyors in the area and from private wells in the area. In addition, we are also in the process of writing a health consultation that describes the perchlorate groundwater contamination west of the Aerojet Superfund site.

Aerojet began operation in 1951. Since that time, Aerojet has manufactured liquid and solid propellants for military and commercial rocket systems and has fabricated, assembled, tested and rehabilitated rocket engines (1). In addition, between 1974 and 1979, Cordova Chemical Company, a wholly-owned subsidiary of Aerojet, manufactured paint components, herbicides, and pharmaceutical products. Over the years, Aerojet and Cordova Chemical disposed of hazardous waste by burial, open burning, discharge into unlined ponds, and injection into deep underground wells (1). Some of these discharges, including perchlorate, have contaminated the environment and have moved off-site of the Aerojet facility boundary (Figure 1). Perchlorate in the groundwater arises from ammonium perchlorate being a main component of solid rocket fuel. In addition to the natural migration of perchlorate-contaminated groundwater from the site, Aerojet is reinjecting treated groundwater, contaminated with perchlorate, at the sites's western boundary. The Regional Water Quality Control Board (RWQCB), the California Department of Toxic Substances Control (DTSC) and the U.S. Environmental Protection Agency (USEPA), are the lead regulatory agencies overseeing groundwater investigation and cleanup at Aerojet, and are also investigating other sources of the perchlorate, such as the McDonnell Douglas (now Boeing) and Purity Oil Sales sites.

Mather Air Force Base Water Service Description

Mather Air Force Base is located to the southwest of the Aerojet site and it is listed on the National Priority List due to soil and groundwater contamination. As part of the Base Realignment and Closure Act, Mather Air Force Base was identified for closure and on

September 30, 1993 the base closed (7). The base was and is essentially composed of several different land uses, served by two water systems, the Main Base and the Family Housing areas. Until the perchlorate contamination was discovered, the two water systems essentially operated independent of each other even though there was an interconnection (8).

The Main Base area is located to the north of the air fields (Figure 2) and this is where all the air force management operations were carried out. The Main Base Water System has 210 connections serving 413 buildings in the administrative and industrial area of the base including the aircraft hangers and the flight line adjacent to the base's runways (8). In 1988, when the base was in operation, approximately 6,200 people worked within the Main Base water System Area . A 29-bed hospital is located in the Main Base area; since the base closure, the hospital is being operated by McClellan Air Force Base. The Main Base area, now called Mather Field, is being used for air cargo service, light industrial and office businesses under the direction of a county redevelopment project. The redevelopment project has been increasingly successful in creating new businesses to relocate or locate at Mather Field. Currently, there are approximately 50-60 businesses employing approximately 1,900 employees. The Main Base water system also serves a transitional family housing unit, Mather Community Campus, that can accommodate several hundred people.

Prior to the discovery of the perchlorate contamination, the Main Base was served by four wells (MB Wells 1,2,3,4) located within the Main Base area (Figure 2) (8). The four wells rotate as the lead well to supply water to the system. The water from the four wells is pumped to a 650,000 gallon ground level reservoir, located near Main Base well #1 (9). As the water is needed in the Main Base area, it is pumped from the storage tank into the distribution system. A 300,000 gallon elevated storage tank is located midway in the distribution system and provides additional storage and pressure in the distribution system (9).

The 650,000 gallon ground level reservoir was taken out of service from December 1995 to June 1997 for repair of defects (9). For some of the time when the 650,000 gallon ground level reservoir was out of commission, the Main Base system was operated partially in manual mode. Specifically, from December 1995 to summer 1996, the well rotation was not automated so demand was often manipulated by hand. Since Main Base well #1 is located close to the Main Base Treatment Plant, this well may have been used more often (9).

The Family Housing area is composed of 414 two- and three-bedroom duplexes, 857 two-, three-, and four bedroom houses, and several common use facilities, including two schools (Mather Heights and Kittyhawk Schools), a teen/youth center, swimming pool, Little League fields, a convenience market, and a gas station (10). A golf course and riding stable are also serviced by the Family Housing water system. In 1988, before the base closed, approximately 4,500 people were serviced by the Family Housing Water System (8). The common use facilities are still in use even though the base has closed. Sacramento County Parks and Recreation operates the recreational and parks areas including the golf course for general use. The housing units are not currently occupied.

The Family Housing area is served by five wells (FH Wells 1, 3, 4, 5 and 6; however, wells 3 and 6 are temporarily out of operation) located within the Family Housing area (Figure 2). Water from the five wells is pumped to a central treatment facility before it is pumped to an elevated 500,000 gallon tank (8). The treatment facility chlorinates the water and removes iron and manganese to improve the esthetic quality of the water.

Even though there is a large plume containing volatile organic compounds (VOCs) such as tetrachloroethylene (PCE) and carbon tetrachloride coming from the contamination that originated from on-site sources, there has been very little VOC contamination detected in Mather wells. The Main Base well #1 had trace amounts of PCE (<0.95 ppb) detected in it. In February 1997 sampling, Main Base well #3 had a detectable amount of PCE (0.97 ppb) detected in it; a sample taken in April 1997 had not detection (<0.5 ppb).

Nitrate concentration in the Main Base wells ranged from 1.3 to 2.2 ppm in 1991 and 1.24 to 1.28 ppm in 1992 (9). Nitrate concentrations in the Family Housing wells ranged from 0.14 to 0.18 ppm in 1991 and <0.01 to 1.5 ppm in 1992. The drinking water standard for nitrate is 45 ppm.

The Main Base system is interconnected in two locations. Prior to the discovery of the perchlorate, there was a pipeline that interconnected the Main Base system with the Family Housing system that was in poor condition and was not used (8). Recently, this interconnection has been upgraded and is currently in use.

The Main Base system is also interconnected with Citizens Utility's Suburban System (8). Citizen Utility shut down one of its Suburban system wells (Citizens Utility well #29) because PCE (originating from Mather) was detected in a monitoring well located upgradient to well #29. Citizens Utilities wanted compensation for the water production loss. The Air Force constructed a one-way intertie leading from the Main Base system to Citizens Utilities' Suburban System which could provide 900 gallons per minute. The intertie was used to supply water to Citizens Utility's Suburban System from July to November 30, 1995 (8) and from July to October 1996 (10).

DISCUSSION

In late January and early February 1997, Aerojet, as a part of their ongoing monitoring of certain off-site public drinking water wells, detected perchlorate in five off-site public drinking water wells west of Aerojet and north of Mather (none of these wells were Mather wells) (11). To analyze these water samples, Aerojet used a refined or improved analytical method such that instead of a reporting level of 400 ppb, they were able to obtain a detection limit of 35 ppb. (For a more complete history of the perchlorate discovery see Aerojet General Health Consultation-Perchlorate Groundwater Contamination.) These detectable levels of perchlorate exceeded the concentration (4 to 18 ppb) suggested by the USEPA provisional reference dose (1 to 5E-4 mg/kg/day) based on a 70 kg individual consuming 2 liters of water a day (12).

Based on subsequent testing by Aerojet that showed that Main Base well 2 had a level of 120 ppb perchlorate, this well was taken off-line on March 14, 1997. Mather Main Base well 1 was reported to have a level of 67 ppb and it was taken off-line on March 21, 1997.

In March 1997, the Sacramento District field staff of the CDHS Division of Drinking Water (DDW) sampled 41 public water supply wells in the area of the known perchlorate contaminated wells, including seven wells located at Mather Air Force Base and the hosebib at one of the Main Base buildings (13). The well samples were processed by the CDHS's Radiation and Sanitation Laboratory with a quantitation limit of 4 ppb (Table 1). In March 1997, Mather Main Base well #3 had a level of 14 ppb, while well #4 had no detectable levels of perchlorate. Because well #4 was not contaminated, well #4 was put as the lead well to supply water to the ground level reservoir serving the Main Base area and well #3 was placed in a backup mode (14). Mather Family Housing wells #1, #4, and #5 had no detectable levels of perchlorate.

The DDW field staff have continued to play the lead role in monitoring the perchlorate contamination. In April, DDW staff sampled 22 wells, including the four Main Base wells, two irrigation wells serving the Mather Air Force Base golf courses, and three monitoring wells that Mather has installed near a location where they were planning to put another drinking water well (14). In May, DDW staff sampled 43 locations, including five Mather wells (14). In June, DDW staff sampled 47 locations, including four Mather wells (14). In July, DDW staff analyzed water from 40 locations, including five Mather wells (15). In August, DDW staff analyzed water from 42 locations, including five Mather wells (16). No perchlorate has been detected in Family Housing wells #1, 4, and 5, the golf course wells, Main Base well #4, and in the three monitoring wells (Table 1). The Main Base well #3 is in-line as a backup and it has levels of perchlorate around 18 ppb; in July, perchlorate was detected at 19 ppb in Main Base well #3 (Table 1).

Community Concerns

The Mather Air Force Base Conversion Agency of the U.S. Air Force send periodic updates to interested persons and nearby residences and commercial businesses about the Mather site investigations and cleanup activities. In the spring 1997 fact sheet, the Base Conversion Agency summarized the perchlorate contamination that had been found at Mather Field and the actions that had and would be taken to protect the water supply (17). They also offered the perchlorate fact sheet created by CDHS cooperative agreement staff to anyone who requested a copy (18). Air Force Base Conversion Agency staff and people associated with the county redevelopment effort have not reported much interest in the perchlorate problem (9).

Pathway Analysis

It is not clear when the perchlorate contamination reached the Mather wells, because Aerojet had previously been using an analytical method to monitor for perchlorate that was not sensitive enough to adequately assess the migration of perchlorate. In fact, until recently, Aerojet had a perchlorate reporting level to RWQCB of 400 ppb, based on the fact that the older method had a

practical quantitation limit for perchlorate of 400 ppb (19). It was not until Aerojet improved upon the analytical method they had been using and were able to obtain lower detection limits, that the perchlorate contamination could be adequately addressed.

Though we do not have good monitoring information, we do know that Aerojet began reinjecting water from their treatment plants on the west boundary of the site in 1984 and 1985, which continues to this day (20). Thus, assuming that it took a couple of years for the perchlorate to move from the reinjection wells to the Main Base wells, perchlorate has probably been a contaminant in the Main Base wells since 1987/1988.

The exposure to the perchlorate contamination in Mather Main Base wells #1 ceased on March 14, 1997 when the Mather Air Force Base Conversion Agency learned of the perchlorate contamination and took it off-line (14). The exposure to the perchlorate contamination in Mather Main Base wells #2 ceased on March 21, 1997 when the Mather Air Force Base Conversion Agency took it off-line (14).

Main Base well #3, which is contaminated with perchlorate in the range of 14-19 ppb, has been the back-up well to Main Base well #4 since April 1, 1997 (14). Main Base well #3 has been used periodically, but it is anticipated that 35-50% blending would occur in the ground level reservoir, thus reducing perchlorate level below 18 ppb prior to entering the distribution system (9).

In August, the upgraded intertie between Family Housing and the Main Base system went on-line. Since that time, the Family Housing intertie has been the lead source for Main Base water with Main Base well #4 as the first backup source, and Main Base well #3 as the second backup source.

From the time when perchlorate may have first affected the Main Base wells, approximately 1987/1988, until the base was closed on September 3, 1993, the Main Base supplied water to 6,200 personnel (8). Since September 30, 1993, there has been a steady increase in the reuse and development of the former base. For instance in 1994, it was estimated that 1,000 people were being served by the Main Base wells (8), while, in 1997, it is estimated that Main Base serves water to 1,900 employees and approximately 70 people using the transitional housing for up to a two year period (21). (Customers of the Citizens Utilities were also served water from the Main Base water system in parts of 1995 and 1996. That exposure is reviewed in a separate health consultation.)

For a target population to be exposed to environmental contamination, there must be a mechanism by which that contamination comes into direct contact with the target population. An exposure pathway is the description of this mechanism (22). A completed exposure pathway consists of five parts: a source of contamination, an environmental medium and transport mechanism, a point of exposure, a route of exposure, and a receptor population. For a population to be exposed to an environmental contamination, a completed exposure pathway (all five elements) must be present.

In the next few paragraphs, CDHS will describe how we evaluated the completed exposure pathway related to the perchlorate contamination of the Main Base well water for four different receptor populations: worker in the Main Base Area, frequent adult customer/visitor to a business served by the Main Base well system, adult using the transitional housing, and adult patient at the McClellan Hospital in the Main Base Area (Table 2). As of early April when Main Base well #4 became the permanent lead well, there has been no water contaminated with perchlorate being added to the Main Base water system. Thus, this exposure does not currently exist, it is a completed exposure pathway in the past.

When evaluating the potential health impact from exposure to contaminated potable water, CDHS considered all routes of exposure to perchlorate in the water. The most important route of exposure is through ingestion of the water. We did not evaluate exposure from eating homegrown fruits and vegetables that were irrigated with perchlorate-contaminated water, because we do not believe that there are any residential gardens or agricultural uses of the Main Base water. We did not evaluate inhalation exposure to perchlorate in the potable water because perchlorate is not volatile (does not become a gas).

For certain chemicals, skin contact with contaminated water can be an important route of exposure. Generally speaking, skin absorption of a chemical is based on how much that chemical likes to be in fat-like surroundings. Inorganic ions like perchlorate do not like being in fat-like surroundings and thus their uptake by the skin, a fat-like environment, are typically less than 10% and frequently less than 1%.Since the permeability characteristic for perchlorate is not known, we used the permeability characteristic of another anion, chloride (1×10^{-10} cm/sec) to evaluate skin exposure to perchlorate (23). We found that skin contact would result in an exposure dose estimate that is less than 0.0005% of the dose estimate that would be received by ingesting the water. Therefore, CDHS focused on ingestion in calculating dose estimates.

The amount of Main Base water system perchlorate-contaminated water that is ingested will be determined for each exposure pathway; however, when the route of exposure is ingestion, it will be assumed that there is 100% absorption of perchlorate into the body from the gut from the amount water that is ingested.

Toxicological Evaluation

This health consultation focuses on perchlorate exposure and thus the toxicological evaluation will focus on perchlorate. CDHS acknowledges that there very, low levels, well below the drinking water standard, of nitrates and nitrite, naturally-occurring, agriculturally-related and perhaps site-related, in the well water; however, the affect of nitrates/nitrites in combination with perchlorate will not be evaluated due to lack of toxicological information that would allow such an evaluation.

Most of the information about the toxicity of perchlorate comes from studies of potassium perchlorate as a treatment for hyperthyroidism, resulting from Graves' Disease. Perchlorate inhibits the secretion of thyroid hormones (and can thus relieve the symptoms of Graves' Disease) by competitively inhibiting the accumulation of iodide in the thyroid (24). Discontinued administration of the ammonium perchlorate to Graves' Disease patients does result in a return to their hyperthyroid condition (25). People who have been treated with perchlorate have reported gastrointestinal irritation, skin rash, and hematological effects including agranulocytosis, aplastic anemia, and lymphadenopathy (24). The severe hematological effects seem to be more likely to occur when large doses of more than 1,000 mg/day (approximately 14 mg/kg/day for a 154 pound man) are used (26).

Potassium perchlorate was extensively used for treatment of Graves' Disease patients in the late 1950s and 1960s. After the reports of the severe hematological effects, potassium perchlorate was not used for many years (27). In the early 1980s, physicians in Europe began using it again for the treatment of Graves Disease, and reporting no serious side effects occurring as long as the dose was kept below 1,000 mg/day (approximately 14 mg/kg/day for a 154 pound man) (26). In addition, potassium perchlorate has also been found helpful in treating thyrotoxicosis resulting as a side effect from other drug therapies (28-32).

There are only a few studies of the short-term exposure in persons without Graves Disease (33). The animal studies that have been conducted have also involved short-term exposures and the doses were too high to see a level where there was no effect on the thyroid. Both human and animal studies have primarily examined the effects of perchlorate on the thyroid, interference with the production of thyroid hormones resulting in a below normal level of thyroid hormone in circulation (hypothyroidism). The effect of perchlorate on systems other than the thyroid needs to be explored, especially, effects on the blood system (described above) and developmental effects (described below).

Children are not little adults, their bodies are not fully developed, and may not respond to a perchlorate in the same manner as an adult. For instance, thyroid hormone is critical to normal brain and physical development, and the critical period for this dependency on thyroid hormone begins in the uterus and extends up until three years of age. After the age of 3, thyroid hormone continues to play a primary role in physical development until puberty.

Thus, a low level or absence of thyroid hormone in utero or in childhood may lead to <u>irreversible</u> mental retardation and retarded physical growth.

Perchlorate can cross the placenta and thus could affect the developing fetus, though these effects have not been studied in humans. It is known, however, that drugs currently being used to treat Graves' Disease such as propylthiouracil do cross the placenta and can produce neonatal hypothyroidism (34, 35) and fetal in utero goiter (enlargement of the thyroid) (36-38). In fact, because the developing fetus's thyroid is immature, propylthiouracil is a more potent suppressor of thyroid function in the fetus than in the mother (39).

In a study of the effects of potassium perchlorate (740 mg/kg/day for the mother) fed to pregnant guinea pigs during pregnancy, a 15-fold enlargement of thyroid of the newborns was noted, even though no increase in size of the mother's thyroids occurred (40). Thyroid hormone levels of the newborn guinea pig were not measured in this study. Another animal study in which the mother was given fairly high levels of perchlorate, also resulted in increased thyroid weight in the offspring and the mother (41). At this time, it is unclear whether lower doses of perchlorate would affect the thyroid of the developing fetus and young child and thus affect thyroid function at a time when normal thyroid hormone production is important to brain development.

There are animal studies underway which are exploring the toxicity of perchlorate, including effects on the immune system and developmental effects (see the Recommendations section at the end of the text for more information).

In 1992 and 1995, USEPA staff reviewed the perchlorate toxicology studies and derived a provisional reference dose (RfD) (12, 33). An RfD is a dose to which a person could be exposed over long-term period without having any appreciable risk of a noncancer health effect. The USEPA applied an uncertainty factor of 300 or 1000 to the No Observable Adverse Effect Level of 0.14 mg/kg/day (NOAEL) (33, 42) to derive an RfD of 1 to 5 x 10-4 mg/kg/day (12). (If one assumes that a person drinks 2 liters/day of water and weighs 70 kilograms, the reference dose range corresponds to an acceptable range of perchlorate in drinking water of 4 to 18 ppb).

The uncertainty factor of 300 or 1000 is derived from multiplying the following (12):

* An uncertainty factor of 10 to account for extrapolation from the acute exposure in the NOAEL study to chronic exposure of an RfD;

* An uncertainty factor for database deficiencies (3 or 10) to account for data limitations including limited data on subchronic and chronic exposure to low doses of perchlorate, limited data on other organ system effects, limited data on the effects on the hematopoietic system, and a lack of reproductive and multigenerational data;

* An uncertainty factor of 10 to protect sensitive subpopulations which would include groups such as hypothyroid patients and individuals with low iodine diets or with genetically impaired iodine accumulation.

The only information about the possible carcinogenicity of perchlorate has to do with cancers of the follicular thyroid cells (12). Interference with the normal thyroid-pituitary feedback mechanism, such as that caused by perchlorate, can theoretically lead to thyroid follicular cell neoplasia. Several animal studies found that thyroid tumors were induced in both rats and mice by long-term administration of high doses of perchlorate. However, humans are not supposed to be as sensitive as the rat to thyroid cancer (43, 44). Since perchlorate's possible carcinogenic effects on the thyroid are based on the same mechanism (interfering with the thyroid-pituitary

homeostasis) that determines its noncarcinogenic effects, it may be appropriate to consider the RfD as a dose which does not pose a significant risk of thyroid cancer (33).

It is even harder to determine whether or not perchlorate exposure can cause any other type of cancer. If a link is discovered, it will probably be based on perchlorate acting not as a mutagen (causing genetic changes) but rather as a growth promoter, an effect associated with a threshold. In other words, below a certain threshold, perchlorate would not have cancer-causing effects. More toxicological information is needed to ascertain whether perchlorate can cause cancer and if it can, at what dose this effect may start occurring.

Using USEPA's provisional reference dose (0.0001 to 0.0005 mg/kg/day) based on perchlorate's effect on the thyroid (12), CDHS evaluated the noncancer (thyroid) health impact of the exposure to perchlorate-contaminated water from Mather's Main Base water system that occurred prior to the discovery and discontinued use of the perchlorate-contaminated wells (Table 2). We evaluated this completed exposure pathway for four different receptor populations: worker in the Main Base Area, frequent adult customer/visitor to a business served by the Main Base well system, adult using the transitional housing, and adult patient at the McClellan Hospital in the Main Base Area (Table 2).

Since the water that services the Main Base comes a storage tank where water from the wells may be mixed and well usage was rotated among the four wells, it is hard to estimate what concentration of perchlorate was delivered to the user. It may be possible to recreate past exposures through a time intensive analysis of the historical documentation of the Main Base well logs and other water system documentation. However, for this health consultation, we will instead evaluate three well contribution scenarios: Main Base well #1 was delivering 100% of the water, Main Base well #2 was delivering 100% of the water, and all wells were equally contributing to the water being delivered to the user (so the concentration of perchlorate being delivered to the user in the third scenario is the average of the four well levels). By evaluating these three scenarios, we will be considering the worst case scenario, when well #2 was the lead well; the second worst situation, when well #1 was the lead well; and a rough approximation of the automated, rotational use of the wells with the storage tank being the place where the blending of the water occurs.

CDHS will use the concentrations of perchlorate measured in the wells when DDW sampled in March 1997 (Table 1), since these are the measurements that correspond most closely in time with when these wells were taken off-line (Main Base wells #1 and 2) or put in the backup mode (Main Base well #3). Thus we will be evaluating exposure based on recent perchlorate concentrations. It does seem that the perchlorate levels in Mather wells (Table 1) and in other water purveyor wells (see other health consultations) have fluctuated a bit over the past several months, but on the whole seem to relatively constant. This would mean that the dose estimates that we calculate may reflect exposures that have occurred in the past. However, because it is expected that the concentrations do change over a period of several years, and there is no good

perchlorate concentration information prior to 1997, it is not possible to evaluate exposures that occurred as long ago as 1988-1994

Though it is possible to estimate a dose for a child drinking the Mather Main Base water, CDHS did not calculate this dose because we are not confident about how to interpret the dose estimate. To compare the estimate of a child's dose with toxicological information based on adult exposure ignores the fact that a child is not a small adult, especially when it comes to the importance of the thyroid in normal brain development (see above). Thus, until there is more information about perchlorate's effect on children, CDHS is not able to evaluate past and current exposures to a young child drinking the Mather Main Base water whether visiting the base or staying at the transitional housing.

Worker exposure at a Main Base Area business: CDHS estimated the exposure for a worker who worked eight hours a day, five days a week, for 50 weeks of the year (assumes a two week vacation) at a business that is served by the Main Base water system (Table 3 is a list of the exposure parameters used in the toxicological evaluation). CDHS assumed that the worker is involved in manual labor and thus drank a relatively large quantity of water (3.7 liters/day, the equivalent of 15.6 cups/day) (45). CDHS estimated the dose if the worker was exposed to water as described in the three water contribution scenarios described above.

The estimated dose for worker exposure to water from the Main Base water system in each of the three well contribution scenarios (0.00081, 0.0015, and 0.00062 mg/kg/day, respectively) exceeds the provisional reference dose range (0.0001 to 0.0005 mg/kg/day) which means that noncancer (thyroid depression) health effects may have occurred when workers in the Mather Base Area were exposed to water from these wells. However, because there is a very large uncertainty factor associated with the provisional reference dose and the estimated doses do not approach the NOAEL (0.14 mg/kg/day), it is unlikely that these exposures did cause any noncancer health effects.

Frequent Adult customer or visitor exposure at Main Base businesses: CDHS estimated the exposure for a adult visitor or adult customer who went once a day, five days a week, for 50 weeks of the year (assumes a two week vacation) to a business in the Main Base Area (Table 3 is a list of the exposure parameters used in the toxicological evaluation). CDHS will assume that the adult visitor/customer drank a cup of water (0.24 liters) per trip to the business. CDHS estimated the dose if the frequent Adult customer/visitor was exposed to water as described in the three water contribution scenarios described above.

The estimated dose for frequent Adult customer/visitor exposure to water from the Main Base water system in each of the three well contribution scenarios (0.00016, 0.00028, and 0.00012 mg/kg/day, respectively) does not exceed the provisional reference dose range (0.0001 to 0.0005 mg/kg/day). This means that noncancer (thyroid depression) health effects would not have occurred to the frequent Adult customer/visitor drinking or washing with water from the Main Base water system.

Temporary Adult resident at the transitional housing in Main Base Area: CDHS estimated the exposure for a person who used the transitional housing, for the maximum allowable time, 2 years. We assumed that the temporary Adult resident may spend as much as 24 hours per day during their stay at the transitional housing (Table 3 is a list of the exposure parameters used in the toxicological evaluation). CDHS estimated the dose if the temporary Adult resident is exposed to water as described in the three water contribution scenarios described above.

The estimated dose for temporary Adult resident exposure to water from the Main Base water system in each of the three well contribution scenarios (0.0012, 0.0021, and 0.00091 mg/kg/day, respectively) exceeds the provisional reference dose range (0.0001 to 0.0005 mg/kg/day) which means that noncancer (thyroid depression) health effects may have occurred when temporary Adult residents of the transitional housing were exposed to water from the Main Base wells. However, because there is a very large uncertainty factor associated with the provisional reference dose and the estimated doses do not approach the NOAEL (0.14 mg/kg/day), it is unlikely that these exposures did cause any noncancer health effects.

Patient at the McClellan Hospital in the Main Base Area: CDHS estimated the exposure for a person who stayed at the hospital for a two-weeks (Table 3 is a list of the exposure parameters used in the toxicological evaluation). CDHS estimated the dose if the adult patient is exposed to to water as described in the three water contribution scenarios described above.

The estimated dose for the adult patient's exposure to water from the Main Base water system in each of the three well contribution scenarios (0.0019, 0.0034, and 0.0015 mg/kg/day, respectively) exceeds the provisional reference dose range (0.0001 to 0.0005 mg/kg/day) which means that noncancer (thyroid depression) health effects may have occurred when adult patient at the McClellan Hospital was exposed to water from the Main Base wells. Since a patient's health is probably already compromised, the large uncertainty factor built into the provisional reference dose may not necessarily ensure that a health impact did not occur.

CONCLUSION

Based upon the information reviewed, there was a completed exposure pathway to perchlorate-contaminated water in the Main Base Water System at Mather Air Force Base. This exposure may have occurred to patients at the base hospital, employees, customers, and visitors in the Main Base Area of the base before it was closed in 1993; however, the levels of perchlorate in the well water at that time are not known. Thus, it is was not possible in this health consultation to evaluate the health impact of those exposures.

Since the closing of the base in 1993, there has been a mixed use of the base. The area that is served by the Main Base area has been developed by Sacramento County to be an air cargo field with commercial and light industrial areas. McClellan Air Force Base is now operating the hospital at Mather and the county has a transitional housing unit located in the area served by the

Main Base water system. Using the recent Main Base well sampling results for perchlorate, CDHS evaluated exposures to employees, adult customers/visitors, temporary adult residents and adult patients. There are no permanent residences located in the area served by the Main Base water system.

It is difficult to predict when the perchlorate first contaminated the Mather Main Base wells but it may have been as early as 1987. As of August 1997, when the upgraded intertie with the Family Housing unit went on-line, exposure to perchlorate contaminated water probably is no longer occurring in the Mather Main Base area because the wells contaminated with perchlorate have either been taken off-line or are only used for emergency purposes.

The perchlorate concentration in two Mather Main Base drinking water wells (Main Base wells #1 and 2) exceeds a concentration (4 to 18 ppb) suggested by the USEPA provisional reference dose based on a 70 kg individual consuming two liters of water a day. Since the uncertainty factors are supposed to account for the somewhat limited toxicological information, it is conceivable that as more toxicological data becomes available, a change in the (provisional) reference dose may occur.

The estimated dose for a Mather Main Base worker, temporary adult resident at the transitional housing unit, and adult patient at the hospital in the Main Base Area exposed to water from well #1, #2 or an average of the four Main Base wells exceeds the provisional reference dose range (0.0001 to 0.0005 mg/kg/day) which means that noncancer (thyroid depression) health effects may have occurred when the workers, temporary adult resident, and adult patients were exposed to water from the Main Base wells. However, because there is a very large uncertainty factor associated with the provisional reference dose and the estimated doses do not approach the NOAEL, it is unlikely that these exposures did cause any noncancer health effects to the workers and temporary Adult residents. Since a patient's health is probably already compromised, the large uncertainty factor built into the provisional reference dose may not necessarily ensure that a health impact did not occur.

The estimated dose for the frequent adult resident/visitor exposed to water from well #1, #2 or an average of the four Main Base wells does not exceed the provisional reference dose range. This means that noncancer (thyroid depression) health effects would not have occurred to the frequent adult resident/visitor drinking or washing with water at the Main Base area.

Based upon the information available at the time this health consultation was written, CDHS concludes that well water from Main Base wells #1, #2, and a combination of those wells may pose a health threat to the users of that water.

PUBLIC HEALTH RECOMMENDATIONS AND ACTIONS

The Public Health Recommendations and Actions Plan (PHRAP) for this site contains a description of actions taken, to be taken, or under consideration by ATSDR and CDHS at and

near the site. The purpose of the PHRAP is to ensure that this health consultation not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The CDHS and ATSDR will follow-up on this plan to ensure that actions are carried out.

Actions Completed

1. Mather Air Force Base Conversion Agency provided an alternative, and perchlorate-free water supply to the Main Base Water System.

2. CDHS prepared a fact sheet about perchlorate and health. CDHS made this fact sheet available to the affected water purveyors including the Mather Air Force Base Conversion Agency.

3. Mather Air Force Base Conversion Agency communicated with the Mather Air Force Base site mailing list on one occasion ragarding perchlorate level in affected wells, and mentioned in this communication that the perchlorate fact sheet developed by CDHS cooperative agreement staff was available upon request.

Actions Planned:

1. The Air Force and the Perchlorate Study Group (a number of manufacturers and users of perchlorate) are sponsoring an investigation into fate and transport questions regarding perchlorate. For instance, they will investigate if is perchlorate is taken up and bioconcentrated by vegetable crops and the skin permeability of perchlorate.

2. The Air Force and the Perchlorate Study Group are also sponsoring a series of animal studies to address some of the information lacking in understanding perchlorate toxicology. CDHS cooperative agreement staff along with other state and federal scientists, were asked by the Air Force to recommend and oversee the planning of the animal studies. As of August 1997, the study protocols have been finalized and the process of choosing a laboratory to conduct the studies is underway. A report on the studies is expected in mid-summer 1998.

Recommendations for Further Action:

1. Use Mather Main Base wells #1, 2, and 3 for fire protection only until perchlorate levels fall below 18 ppb.

2. Continue communicating with the Mather Main Base water customers about the perchlorate issue.

3. Continue monitoring drinking water wells for perchlorate, and discontinue using wells that have levels that exceed the safe level for perchlorate (currently 18 ppb).

4. If indicated based on new toxicological information, review toxicological evaluation of past and current perchlorate exposures in the Main Base area.

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CERTIFICATION

The Perchlorate Contamination in the Mather Air Force Water Service Area, Aerojet-General Corporation Health Consultation was prepared by the California Department of Health Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.

Technical Project Officer, SPS, SSAB, DHAC

The Division of Health Assessment and Consultation, ATSDR, has reviewed this health consultation, and concurs with its findings.

Chief, SPS, SSAB, DHAC, ATSDR

Table 1: Mathers Air Force Base Drinking Water Well Descriptions and Perchlorate Sampling Results

Well	Drawing Depth (ft bgs)	Status of Well	Capacity (gpm)	PERCHLORATE ANALYSIS (ppb)						
				2/97	3/25/97	4/10/97	5/13/97	6/19/97	7/9/97	8/14/97
Main Base -Well 1	262-531	Off-line on 3/21/97	1,130	ns	67	72	ns	ns	ns	ns
Main Base -Well 2	186-494	Off-line on 3/14/97	900	ns	120	130	ns	ns	ns	ns
Main Base -Well 3	249-501	Back up status on 4/1/97	900	ns	14	16	ns	17	19	18
Main Base -Well 4	246-500		670	ns	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Family Housing - Well 1	280-500		1,350	ns	<4.0	ns	<4.0	<4.0	<4.0	<4.0
Family Housing - Well 2	205-500	Destroyed								
Family Housing - Well 3	348-400	Temporarily off-line	1,350	ns	ns	ns	ns	ns	ns	ns
Family Housing - Well 4	360-570		2,200	ns	<4.0	ns	<4.0	<4.0	<4.0	<4.0
Family Housing - Well 5	450-544		1,500	ns	<4.0	ns	<4.0	na	<4.0	<4.0
Family Housing - Well 6	246-409	Temporarily off-line	1,900	ns	ns	ns	ns	ns	ns	ns

ns= not sampled ft bgs= feet below ground surface gpm= gallons per minute

Data from references (8, 13, 15, 16)

**Table 2. Perchlorate Contamination in the Main Base Area-
Completed Exposure Pathway for Different Receptor Populations**

Receptor Group Pathway Name	Source	Environmental medium	Point of Exposure	Route of Exposure	Exposed Population	Time
Worker exposure at Mather Main Base Area businesses	Aerojet, McDonnell Douglas (?)	Groundwater wells in the Main Base Water System	Business Tap	Ingestion	Workers	Past
Frequent customer or visitor at Mather Main Base Area businesses	Aerojet, McDonnell Douglas (?)	Groundwater wells in the Main Base Water System	Business Tap	Ingestion	Frequent customer; Frequent visitor	Past
Temporary resident at transitional housing in Main Base Area	Aerojet, McDonnell Douglas (?)	Groundwater wells in the Main Base Water System	Transistional Housing Tap	Ingestion	Temporary resident	Past

Table 3. Exposure Factors for Each Receptor Population of the Completed Exposure Pathway at the Main Base Area

Pathway Name	Exposure Parameter	Value
Worker exposure at a Mather Main Base Area business	Injestion Rate	3.7 liters (15.6cups)/day
	Body Weight	70 kilograms (154 pounds)
	Exposure Frequency	8 hours/day 5 days/week 50 weeks/year
	Averaging Factor	365 days/year
Frequent customer or visitor at a Mather Main Base Area business	Ingestion Rate	0.24 liter (1 cup)/visit
	Body Weight	70 kilograms (154 pounds)
	Exposure Frequency	5 visits/week 50 weeks/year
	Averaging Factor	365 days/year
Temporary resident at the transitional housing in the Main Base Area	Injestion Rate	2 liters (8.4 cups)/day
	Body Weight	70 kilograms (154 pounds)
	Exposure Frequency	15 hours/day 7 days/week 14 weeks/year
	Averaging Factor	24 hours/day 98 days/year
Patient at the McClellan Hospital in the Main Base Area	Injestion Rate	2 liters (8.4 cups)/day
	Body Weight	70 kilograms (154 pounds)
	Exposure Frequency	7 days/week 14 weeks/year
	Averaging Factor	14 days/year

Figure 1
Perchlorate Groundwater Plume in Relation to Aerojet and Mather Air Force Base

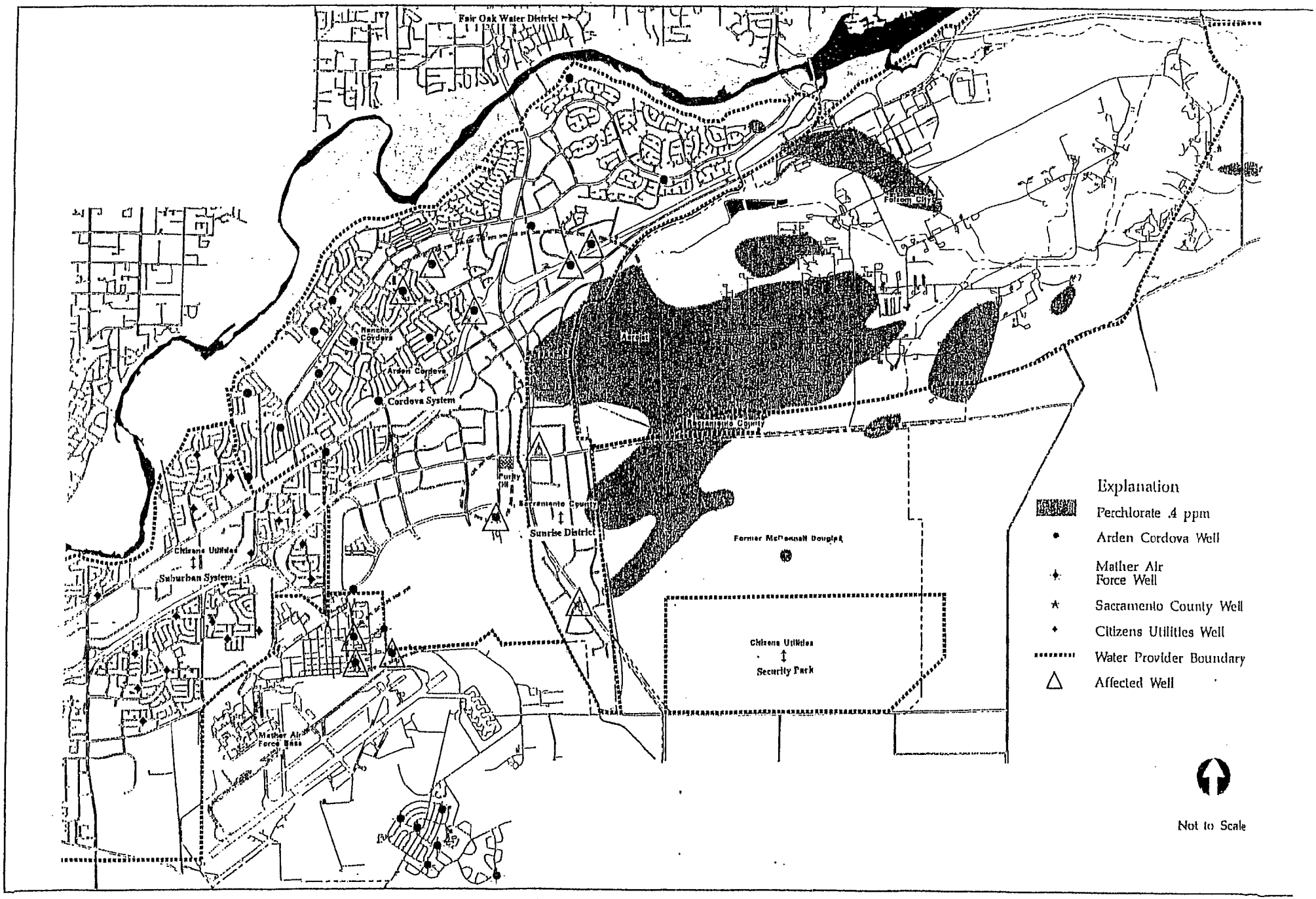
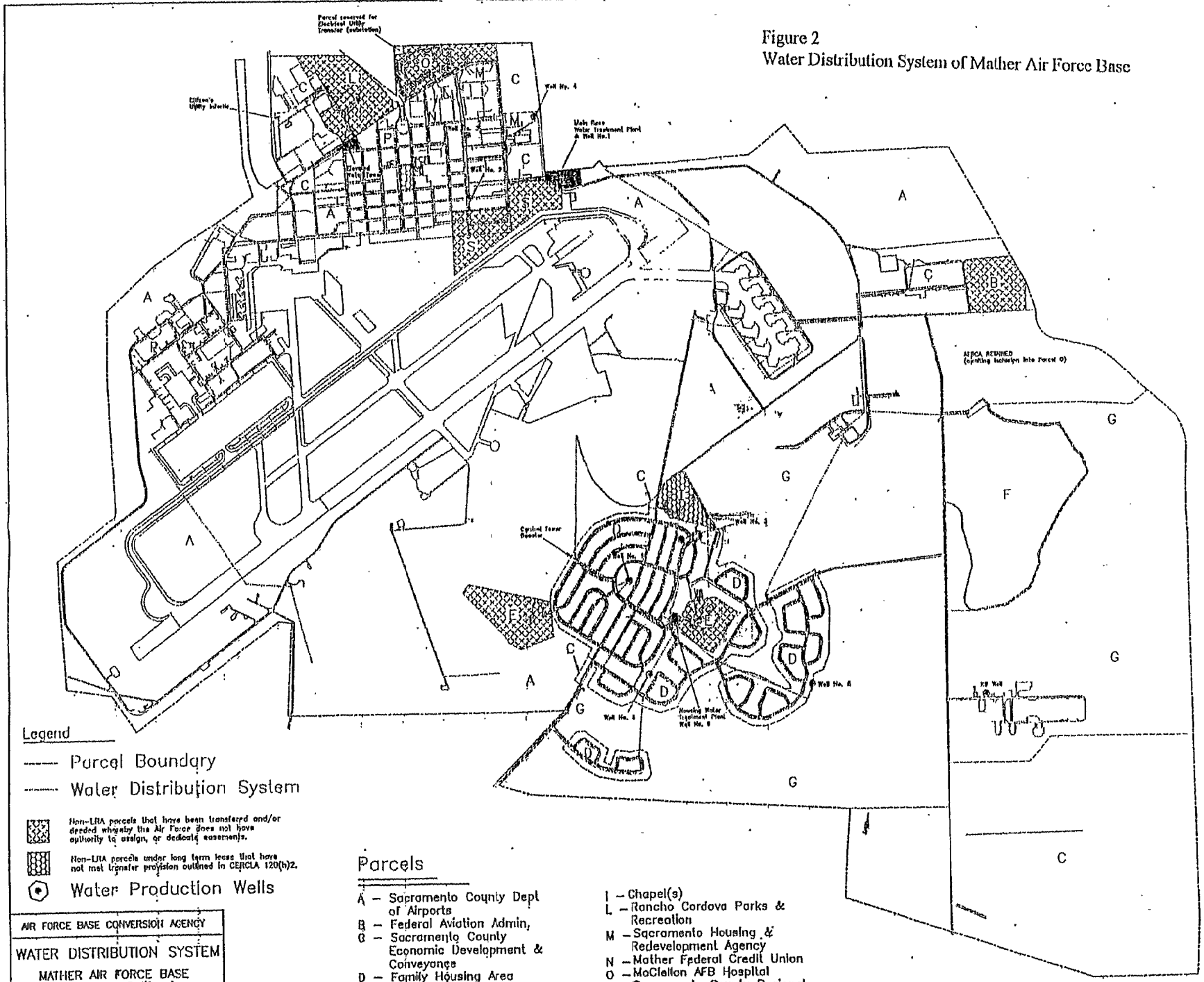


Figure 2
Water Distribution System of Mather Air Force Base



APPENDIX A. RESPONSE TO COMMENTS FROM SITE TEAM REVIEW

In 1995, EHIB formed a site team to assist us in identifying public health concerns and to oversee what we do during the health assessment process for the Aerojet General site. The site team is composed of community residents, state and federal environmental and health agency staff, Aerojet staff, as well as EHIB staff. Health consultations that are produced as apart of the health assessment process are released for comment to site team prior to them becoming final. We received comments on this health consultation from the Drinking Water Branch of CDHS, U.S. EPA, DTSC, Aerojet, and RWQCB. In this appendix, we will respond to the submitted comments. (Some of the commenters used the Cordova Water System Health Consult as the basis for their comments and asked them to be applied to other health consultations when applicable. Thus, some of the comments make reference to the Cordova Water System and not the Sacramento County Sunrise District, but we included the comment in this health consultation if it seemed applicable.)

COMMENTS RECEIVED FROM THE DRINKING WATER BRANCH OF CDHS

The Drinking Water Branch of CDHS regulates water purveyors in the state, and their comments were minor technical corrections to the numbers we cited in the text. These corrections were made to the original document.

COMMENTS RECEIVED FROM THE U.S ENVIRONMENTAL PROTECTION AGENCY

The EPA offers the following comments for your consideration:

USEPA comment: Page 7 - fourth sentence - the statement that "ammonium perchlorate has relevant physical and chemical characteristics similar to cadmium chloride does not appear to be justified. Although both of these compounds are salts, on dissolution (a necessary step in absorption) perchlorate would become an anion (negative charge) and cadmium would become a cation (positive charge). Therefore, one could conclude on this basis alone that cadmium would not be an appropriate surrogate for perchlorate. Comment applies to all reports but Fair Oaks Water District Report.

CDHS response: According to a highly regarded dermal absorption reference source, the permeability of charged ions is extremely low and membranes appear to be more permeable to cations than anions (46). *Thus, the comparison of perchlorate should not be made between the cation, cadmium, but the anion, chloride, that is found when cadmium chloride is in solution.*

USEPA comment: Page 8 - third paragraph - NOAEL term use - The NOAEL is an experimentally derived value that is often used as a basis for the RfD, however, the NOAEL is not regarded by EPA as a value that "would not be expected to be associated with any adverse

effect". Rather, this definition better fits the RfD that is derived from a NOAEL after considering uncertainties in the database. Comment applies to all reports but Fair Oaks Water District Report.

CDHS response: We have corrected the use of NOAEL and RfD in the text.

USEPA comment: Page 23 -Table 3 - Worker exposure - The tap water ingestion rate for workers is listed as (3.7 liters/day) which is almost twice the assumption that is used for a residential scenario. Should this be 0.37? This applies to Mather Air Force Base Water Service Area Report Table 3 - page 21 and the Sunrise District of the Sacramento County Water Service Report Table 2 - page 18. Also, the Citizens Utilities' Suburban & Security Park Water Service Areas Report Table 3 - page 19 lists worker exposure at 2.0 liters/day should this be 0.37?

CDHS response: We are using a reference from USEPA document entitled "Exposure Factors Handbook", published in 1989. In this document, the total fluid intake for a moderately active man is cited as being 3.7 liters/day. This document cites the Report of the Task Group on Reference Man from the International Commission on Radiological Protection, published in 1981 for this number. This higher intake of water does seem appropriate given the labor-intensive commercial businesses that are located near the perchlorate-contaminated wells.

USEPA comment: Figure 1 - Is it possible to make the Cordova System standout? Found figure hard to use.

CDHS response: Unfortunately, this figure is copied from a hard copy and is not electronically produced, so it is probably not possible to improve upon the quality.

USEPA comment: In discussions with the USEPA RPM for Mathers, she indicated exposure had ended at Mathers.

CDHS response: The description of the Mather Base system is based on conversations we have had with Mather Base Conversion Agency staff, and according to them, as of the time when well #3 was put in the backup mode to well#4, April 1997, no perchlorate-contaminated water has been added to the Main Base System. This is stated on page 6 of the health consultation.

COMMENTS RECEIVED FROM THE CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

Below are DTSC's comments which may be considered as the documents are finalized.

DTSC comment: In the "Exposure Pathways" sections of the Arden Cordova, Mather Air Force Base and the Sacramento County water district consultations, it is stated that Aerojet began reinjecting water from their treatment plants on the west boundary of the site in 1984 and 1985. The assumption is then made that it took "a couple of years for the perchlorate to move from the

reinjection wells" to the water district's wells. An accurate assessment of when the perchlorate contamination occurred and the location of the source of the perchlorate cannot be made without further information and analysis. The reinjection field nay not be the source of the perchlorate contamination in many of the affected wells. Aerojet is currently investigating the extent of the perchlorate contamination to the west of its facility pursuant to an order from the Regional Water Quality Control Board. A technical memorandum documenting the results of that investigation is currently scheduled to be submitted in May of 1998, with an Engineering Evaluation/Cost Analysis of remedial alternatives to be submitted in October of 1999. Additional investigations of groundwater to the west of the Inactive Rancho Cordova Test Site (IRCTS), the likely source of perchlorate in several of the affected wells, are also proceeding. DTSC's Project Manager for the IRCTS is Mr. Marvin Woods who can be reached at (916) 255-3666.

CDHS response: EHIB recognizes that a good analysis of the perchlorate migration which would allow us to know when the perchlorate reached the public drinking water supply well, has not yet been done. In fact, we start off the first paragraph in the "Exposure Pathways" section by saying, "It is not clear when the perchlorate contamination reached the Mather wells, ... ". However, since the reinjection of treated water is at least one source of the perchlorate found in some of the drinking water supply wells, we found it was important to share information about this source with the reader. We look forward to reviewing the reports that DTSC is referring to, and hope that they will give a more accurate picture of past well contamination levels.

DTSC comment: In the third paragraph of the consultations, it is stated that the Regional Water Quality Control Board is the lead regulatory agency. While this is correct for some aspects of the project, the lead regulatory agency controlling water district activities is the Department of Health Services, Office of Drinking Water. For matters concerning the Aerojet Superfund Site, the United States Environmental Protection Agency is the lead federal regulatory agency. A co-lead situation exists for certain matters covered under the Aerojet Superfund Site Partial consent Decree (United States District Court, Eastern District of California, Civil Action Nos. CIVS-86-0063-EJG and CIVS-86-0064-EJG).

CDHS response: Being a part of the complex government oversight at this site, we appreciate the clarification to the agency responsibilities. We have tried to rectify this in the text.

COMMENTS RECEIVED FROM AEROJET GENERAL CORPORATION:

Aerojet comment about the attribution of source of the perchlorate in public water supply wells: Each draft Health Consultation assumes that perchlorate being found in public water supply wells came from the Aerojet Operating Plant, specifically from the reinjection wells associated with the GET facilities. There are numerous locations where such references appear. (See, for example, Arden Cordova Health Consultation at:

Page 6, paragraph 2 and page 22, Table 2.) This assumption is used to project length of exposure and concentrations in the wells over time. The conclusion is made for each well, for every water purveyor, regardless of the well's location, chemical concentrations or differing hydrogeological conditions.

We are aware of no detailed evaluation of sources, groundwater conditions and groundwater and contaminant movement undertaken by DHS or any other agency that would support statements in the DHS Consultations that attempt to link perchlorate in a well to an upgradient source, and it does not appear necessary for DHS to ascribe a source to reach its conclusions. The Health Consultations should identify that potential sources of perchlorate include the Aerojet Operating Plant, Purity Oil site, and the McDonnell Douglas (MDC) Site. DHS should not assert that the only source of the perchlorate is the GET facility recharge wells on the Aerojet Operating Plant. Neither should the period of operation of the GET wells form the basis for assumptions of exposure of potential receptors. As the Health Consultations discuss potential sources, it should discuss the various uses of perchlorate, other than in rocket motor manufacturing, such as the use of perchlorate in pyrotechnics (fireworks), explosives and other industrial activities. It should also note that perchloric acid, which is used in various industrial activities, including metal-plating, in laboratories, and in other operations, when released can result in the formation of perchlorate and its movement into soils and groundwater.

Aerojet believes that there have been no health impacts associated with any exposure to perchlorate in the water supply. If the Health Consultations seek to discuss long term impact by assuming exposure for some period (e.g., 10 years), they can do so without assigning a source, but simply by positing the potential for such exposure (without reference to a source) and developing an exposure assessment.

CDHS response: These health consultations are written as a part of CDHS's public health review of the impact of the Aerojet General site. Thus, the documents are written in respect to Aerojet General and not to other sites or facilities. We do recognize that perchlorate may have also gotten into the groundwater from sources other than Aerojet and that is why in last sentence of the third paragraph on page 1, we refer to the RWQCB's investigation of "other sources of the perchlorate such as the McDonnell Douglas (now Boeing) and Purity Oil Sales sites."

Aerojet comment about the toxicology: Aerojet recommends modifications to the discussion on toxicology. We are concerned that the draft consultations do not provide sufficient information about what is known about perchlorate toxicity (thyroid function) and end up, unintentionally, providing a less balanced presentation of the potential for impact and risk. For example, we believe there should be more discussion related to the past use of perchlorate in the treatment of Graves patients and its current use in Europe at very high doses without ill effects. Similarly, we recommend the inclusion of a statement that the mechanism of perchlorate on the thyroid as well as basic thyroid functions are well understood and we believe that the discussion as to exposure associated with children may lead to unnecessary concern and should be changed. Finally, we

believe that there ought to be mention of the ongoing studies being conducted at the direction of the Air Force.

CDHS response: We did provide more information in the toxicology section. For instance, we have added more information about past and current uses of perchlorate and what is known and not known about toxicity to the developing fetus and young child. We did have a reference in the recommendations section about the on-going studies by the Air Force and the Perchlorate Study Group and we have added a sentence in the toxicology section referring the reader to the recommendations section for more information about these studies.

Aerojet comment about the water system operations: The draft Health Consultations, especially in the background sections, contain statements of fact as to the manner of well and system operation of each water entity over time, including detail on well construction and operation in tables. Aerojet has not had an opportunity to complete an evaluation of the accuracy of such statements. We further note that the factual statements generally do not seem to impact the exposure assessment, as the exposure assessment is based upon an assumed concentration that is not generally associated with the specifics of well interties or well operation. We would recommend the Health Consultations state that the water system information is based on current understanding unless DHS has had the opportunity to perform a detailed evaluation of the information.

CDHS response: In each health consultation, we cite the CDHS reports or other reports from which we gained this information. We refer Aerojet to those documents if Aerojet would like to evaluate the accuracy of such statements. We do think it is important to describe for the reader the basic structure of a particular water system; on the other hand, we don't want to add more information then is necessary. We hope that the amount of information we have provided will allow a Mather Main Base System customer to more easily understand that only some of the water wells in the system have been contaminated with perchlorate. By describing the water system information in this document, it also helps us to decide where we might consider follow-up activities, like an exposure dose reconstruction.

Aerojet comment about the Exposure Conclusions: The draft Health Consultations are based upon a set of assumptions, including assumed receptors, exposure rates, and concentrations. From these assumptions, an assumed dose is calculated and then compared to the provisional RfD. We believe that the Health Consultations should carefully describe each assumption upon which the Health Consultations were based, and clarify that these assumptions have not been fully evaluated. For example, a preliminary assessment of proximity to a well is used to determine the type of "receptor" (e.g., resident, worker), but the exposure does not assume any dilution of water from that well with water from any other well.

CDHS response: All of the exposure parameters are listed in the table and a Mather Main Base Water System user can look at these exposure parameters and apply them to their own situation.

Thus it does not seem necessary to explain distributions of exposure parameters or in any other way describe each assumption.

With these general comments identified, we now progress to the specifics. We use the Arden Cordova Health Consultation as the template for our comments, and emphasize that typically the same issue exists in the other draft Health Consultations.

Aerojet comment: Page 1, Paragraph 2 and Throughout: The term "perchlorate contamination" is subject to misinterpretation and references should be to "water containing perchlorate" or like phrase.

CDHS's response: In Webster's New Collegiate Dictionary, it says "contaminate" means "to make impure or unclean". Perchlorate is not typically found in groundwater, as would be the case with certain chemicals like arsenic or sulfates which are naturally occurring in groundwater. Thus it does seem appropriate to describe the "contamination" of groundwater by a chemical such as perchlorate. Likewise, it may be appropriate to describe "water containing arsenic" if you are describing water which contains unusually high levels of arsenic due to natural reasons and arsenic-contaminated water if higher levels than normal may be due to non-natural reasons.

Aerojet comment: Page 1, Paragraph 3: The description of Aerojet operations and Cordova operations has been taken from earlier documents. Aerojet has historically pointed out the inaccuracies in the statements and rather than do so again we recommend, at a minimum, elimination of a reference to Cordova Chemical Company, because we do not believe it used perchlorate. We also recommend an elimination of the reference to the deep injection wells, because they are not relevant to the issue and can result in confusion when there is later discussion about recharge or reinjection wells associated with the GET facilities, which are different wells.

CDHS response: In the background paragraph, we are describing the lay of the land regarding the general site issues and thus we did not directly suggest that Cordova Chemical did use perchlorate, but rather this company was a part of the history of the site. Since perchlorate is reinjected at the site boundary as a part of the GET operations, we do not agree that reference to these should be eliminated.

Aerojet comment: Page 1, Paragraph 3: Delete "property" after "Aerojet's."

CDHS response: This incorrect grammar has been corrected in the text.

Aerojet comment: Page 1, Paragraph 3: Aerojet is not reinjecting treated water at the site's northern boundary.

CDHS response: This has been changed in the text.

Aerojet comment: Page 1, Paragraph 3: The Regional Water Quality Control Board (RB) is not the lead Agency; DTSC, USEPA and RB together provide oversight pursuant to the Partial Consent Decree.

CDHS response: The description of the lead agency/agencies was changed in the text.

Aerojet comment: Page 3, Paragraph 1: The discussion as to detection of perchlorate ought to be rewritten. Prior to the summer of 1996, Aerojet's laboratory used an ion specific electrode method. In 1997 Aerojet's laboratory did not use a different analytical method for perchlorate analysis to obtain the detection limit of 35 ppb but rather refined or improved the sensitivity of the existing ion chromatography method. In addition, it is accurate to say the "method" detection limit.

CDHS response: Based on this comment and a similar comment by other reviewers, the description of the analytical method was revised in the text.

Aerojet comment: Page 3, Third Full Paragraph: The drinking water standard for nitrate as N03 is 45 ppm.

CDHS response: This was corrected in the text.

Aerojet comment: Page 6, Paragraph 1: See the discussion above regarding the history of perchlorate sampling. It is not accurate to say that the analytical method Aerojet had been using was not sensitive to adequately assess the migration of perchlorate. It would be more accurate to state that Aerojet's historical analytical method's practical quantitation limit (PQL) for perchlorate was 400 ppb. As stated previously, there was no "alternative analytical method" used but the existing method was refined or improved and the PQL lowered.

CDHS response: According to the third sentence of the comment, the older method was indeed not sensitive enough to detect the perchlorate contamination. We did, however, revise the text to reflect the last two sentences of the comment.

Aerojet comment: Page 6, Paragraph 2 and following: This paragraph, as well as others below which need not be separately itemized, make an assumption about source and length of exposure which is not presently supportable. See discussion in general comments.

CDHS response: We realize that historical monitoring of the drinking water wells at low enough detection limits and thus we do not have a good understanding of the migration of perchlorate and past exposures to the Mather Main Base System customers. We also realize that we have not yet seen any attempts to model the movement of perchlorate based on groundwater flow patterns and perchlorate levels in monitoring wells. Thus in trying to review the past exposures, we are left to make the best assumptions possible.

Aerojet comment: Page 8, Continuing Paragraph and following: We refer you to the general comments on toxicology above. The draft Health Consultations would be better balanced if there was more discussion related to the use of perchlorate in the treatment of Graves patients and its current use in Europe at very high doses without ill effects. A strong statement that stresses how unlikely it would be to suffer any of these side effects at the levels addressed in the health consultation would be appropriate. In particular, the draft Health Consultations ought to point out that perchlorate has been used successfully and without incident in a fairly large patient population and with a very small number of reports of aplastic anemia even at the very high therapeutic concentrations A statement that the mechanism of perchlorate on the thyroid as well as basic thyroid functions are well understood would help to clarify the presentation. While the provisional RfD is stated as a level in drinking water at 18 ppb, the remaining levels discussed in the document are stated in terms of mg/kg/day. A direct comparison of those doses with the LOAEL/NOAEL and the provisional RfD in the same unit of PPB's would be very useful to give perspective to the dose issue.

CDHS response: As noted on the response to a General Comment from Aerojet, we did provide more information in the toxicology section. For instance, we have added more information about past and current pharmacological uses of perchlorate and what is known and not known about toxicity to the developing fetus and child. We also added a statement in the toxicological section that equates the dose to the drinking water concentrations.

Aerojet comment: Page 8, Continuing and Paragraph 1: The discussion of animal studies should be modified. There are animal studies where toxicologists have interpreted a NOAEL [(e.g. Mannisto (1970) and Caldwell (1996)]. As to the reference to children, in two places there is a discussion that suggests that nothing can be said about children. Aerojet is concerned that the reference might leave the reader with the impression that toxicologists do not consider impact to the thyroid as the focus of the evaluation or it might cause the reader to think that toxicologists view the child's thyroid as not understood. It would be more accurate to state that the mechanism of perchlorate intake on the thyroid is understood and that in evaluating the dose, one must evaluate the possibility that the child may have less iodine reserve which must be considered in evaluating how the child's thyroid compensates in comparison to an adult thyroid. However, any reference should also include the fact that all new-borns are routinely tested for thyroid hormone. levels. Aerojet believes that it would be inappropriate for the Health Consultations to be construed as indicating that children are at risk at the provisional RFD or that exposure to the higher concentrations before well shut down would be associated with any health impact.

While it appears in the text, we believe there should be a clear reference both in the toxicology discussion and in the exposure section, that perchlorate is discharged from the body very quickly and that one would not expect to see any continuing impact on the thyroid once the exposure ends.

CDHS response: See response to previous comment.

Aerojet comment: Page 8, Paragraph 3: Regarding the discussion of safety factors, various toxicologists believe that the hypothyroid individual would not be a sensitive subpopulation. Also, the Health Consultations should recognize that the sensitive subpopulation factor is already being accounted for with respect to DHS comments on exposure of children.

CDHS response: Comment noted.

Aerojet comment: Page 9, Paragraph 3: See discussion above on children. We believe that the two locations of discussion on children should be combined in one location.

CDHS response: See previous responses.

Aerojet comment: Page 9, Third Full Paragraph: The statement that perchlorate levels in Mather wells as well as other water supply wells have remained fairly constant is generally true for the brief period of data collection cited by this consultation but extrapolation back in time is suspect based on the information available.

CDHS response: Comment noted.

Aerojet comment: Page 9, Paragraph 4: Exposure discussion includes the volume of tap water consumed per day in liters and perhaps the inclusion of a unit like the number of 8 oz. glasses per day would benefit the average reader, or public citizen. This could be included in the text and in the Table.

CDHS response: We have added this information to the text and table.

Aerojet comment: Page 9, Paragraph 4 and following: While the Health Consultations do note the potential for mixing of water from various sources within the water distribution system, they assume that the person exposed was exposed at the level reported for the well on the date closest to well closure. The Health Consultations should explain that the evaluation uses the assumed concentration at a well to assess impact of a receptor using the well, even though further evaluation may show that mixing and blending of water during water distribution potentially could occur and reduce the estimated level of exposure.

CDHS response: See previous responses to similar comments.

Aerojet comment: Page 9, Paragraph 4 and Following: There is the repeated statement that the estimated doses for [identified type of exposure] from well # [identified well number] exceeded the provisional RfD range and a conclusion stating "health effects may have occurred." The phrase "may have occurred" could be misinterpreted as it may suggest a higher level of risk than existed, given the low levels of perchlorate found in relation to the provisional NOAEL described. Given the uncertainty factors associated with the provisional RfD, Aerojet believes that it would be more appropriate for the Consultations simply to conclude that the level was over the RFD and

then follow with a conclusion as to the unlikely nature of any health impact. If DHS does continue to want to use "may have occurred" language, then the "may have occurred" language should be clarified when presented by referring to the key assumptions, the exposure assessment, etc., (e.g., the number of 8 ounce glasses of tap water needed to be consumed). The health consultations should also stress that there is a significant range between the provisional RfD of 18 ppb and the NOAEL level translated to 4900 ppb (assuming a NOAEL of .1 4 mg/kg/day and a 70 kilogram male drinking 2 liters per day). It would also be useful either to change the reference of "uncertainty" factors to "safety" factors or use the term uncertainty (safety) factors" for the benefit of the reader.

CDHS response: Comment noted.

Aerojet comment: Page 12, Paragraph 2: See the above comments regarding speculation as to source.

CDHS response: See previous response to similar comments.

Aerojet comment: Page 12, Paragraph 4: There are a number of paragraphs that repeat statements made in the exposure section. See discussion above (page 9) relative to language about dose above the RfD. Aerojet does not believe that it is appropriate to conclude that there "may" have been a "health hazard." If language as to hazard is described, it should not be separated from the DHS assumptions about exposure nor should it be stated without the conclusion as to the unlikeliness of any impact. Aerojet further notes that the various Consultations do not always use the same language on "health hazard," and the differences in language do not appear justified (e.g., see Mather page 12 paragraph 3).

CDHS response: Comment noted.

Aerojet comment: Page 13, Bullet #3 and Page 14, Bullet #4: The reference should be to the Perchlorate Study Group, not Perchlorate Work Group.

CDHS response: This has been corrected in the text.

Aerojet comment: Page 14, Bullet #2: The use of the word "safe" is inappropriate, Reference should be to the provisional RfD.

CDHS response: We have modified the text so as to remove the word "safe".

Aerojet comment: References, No. 17. The citation to the authors should be corrected.

CDHS response: This citation has been corrected.

Aerojet comment on Table 1: We have not had adequate opportunity to evaluate the descriptions of all of the wells and the well system. We note that the comments in the Table are based upon assumptions made as discussed in the text and our comments apply.

CDHS response: Comment noted.

Aerojet comment on Table 2: We believe a "source" category for this Table is inappropriate. Please see general comment above on sources.

CDHS response: Comment noted.

Aerojet comment on Figures 1 and 2: The figures are illegible at this size and difficult for the reader to understand. The figures that present chemical distributions were draft figures and were not prepared for the purpose being used and are not reflective of present understanding of groundwater conditions.

CDHS response: We apologize for the quality of the figures. They are only meant to give the reader a basic layout of the perchlorate flow and the well locations and hopefully, this information is still conveyed with these poor quality figures.

COMMENTS FROM THE CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD

Regional Board staffs comments on the documents are supplied below.

RWQCB General Comment: We recommend that the use of the term "contaminated" be selectively used. Contaminated should be used when the water represents a hazard to the public health. In the case of perchlorate, "contaminated" should not be used when discussing concentrations less than 18 ppb. It is even unclear whether the term should be applied to those concentrations that are currently found in some of the groundwater supply wells (up to 300 ppb). Instead of saying "perchlorate-contaminated water", we would recommend saying "water containing perchlorate".

CDHS response: As was stated under a similar comment raised by Aerojet, in Webster's New Collegiate Dictionary, it says "contaminate" means "to make impure or unclean". Perchlorate is not typically found in groundwater, as would be the case with certain chemicals like arsenic or sulfates which are naturally occurring in groundwater. Thus it does seem appropriate to describe the "contamination" of groundwater by a chemical such as perchlorate. Likewise, it may be appropriate to describe "water containing arsenic" if you are describing water which contains unusually high levels of arsenic due to natural reasons and arsenic-contaminated water if higher levels than normal may be due to non-natural reasons.

RWQCB General Comment: There is a paragraph in each of the health consultations which discusses the "reporting level to the RWQCB" of 400 ppb and a change in method which allowed for a detection level of 35 ppb. In the early 1990's, up until around 1995/96, Aerojet was using a ionspecific electrode to measure perchlorate concentrations in water with a detection level of 400-500 ppb. Aerojet then developed an alternate method using a GC which provided a detection level of 35 ppb and a reporting level of 400 ppb. This method was then used by Aerojet in all work required under the Partial-Consent Decree. In early 1996 RWQCB staff requested Aerojet to report all concentrations between the detection level (35 ppb) and reporting level (400 ppb) as trace. Aerojet was then able to lower their PQL to 100 ppb, while maintaining their detection level at 35 ppb. No method changes were made to get to the lower reporting level. It was in February 1996 that the concentrations in the off-site water supply wells were first reported.

CDHS response: Based on this comment and comments by others, the text was revised.

RWQCB General Comment: When discussing the nitrate levels, make sure that the values reported are designated as milligrams per liter as nitrate, or milligrams per liter as nitrogen. The MCL for nitrate should be expressed in the same units. There are two values for the MCL used in the five health consultations, 20 and 45 mg/l. A single value for the MCL should be used.

CDHS response: We have corrected this in the text.

RWQCB General Comment: We will not supply comments on the toxicological issues presented in the documents. We will rely on the experts at the Department of Health Services to make those evaluations.

CDHS response: Comment noted.

RWQCB comment: Page 2, paragraph 5. The value for the MCL for nitrate should be supplied to allow the reader to determine the significance of the values presented.

CDHS response: We have added the MCL as a reference in the text.

RWQCB comment: Page 5, paragraph 2. Comment B.4. also applies here. This is even a greater stretch given the distance from Aerojet and the IRCTS.

CDHS response: We look forward to the RWQCB or other agencies supplying us with better historical information about the historical movement of perchlorate; in the absence of this, we have clearly stated our assumptions as to when perchlorate contamination may have affected drinking water wells.

RWQCB comment: Page 5, paragraph 5, and page 6, paragraph 3. The page paragraph refers to Main Base well No. 3 , which contains perchlorate, being used periodically as the backup well to Main Base Well No. 4. The page 6 paragraph says that once Main Base Well No. 4 became the

permanent lead well, no water containing perchlorate was being added to the water system. The period of time that Main Base Well No. 3 actually pumped as a backup well to No. 4 should be presented to avoid the apparent discrepancy.

CDHS response: We have corrected the confusion over the use of well #3 after it was placed in the backup mode in April 1997.

RWQCB comment: Page 6, paragraph 2. There is quite a bit of supposition in the statement that "perchlorate was probably a contaminant in the Cordova System wells since 1987". GET E started injecting in 1985 and GET F did not start injecting until late 1988. Without historical data, it is a stretch to provide a specific date. If the 1987 date remains the uncertainties and assumptions used in deriving that date should be supplied. This comment also applies to the second paragraph of page 12.

CDHS response: We look forward to the RWQCB or other agencies supplying us with better historical information about the historical movement of perchlorate; in the absence of this, we have clearly stated our guesses as to when perchlorate contamination may have affected drinking water wells.

RWQCB comment: Page 13, second paragraph. Insert a "the" after "actions" in the second line.

CDHS response: There was a grammatical problem in the sentence, which we have corrected.