HEALTH CONSULTATION

Past Exposure to Drinking Water From On-Base Wells 313 and 314

Kelly Air Force Base

San Antonio, Bexar County, Texas

EPA FACILITY ID: TX2571724333

Prepared by

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PURPOSE AND SUMMARY

This health consultation determines the likelihood of adverse health effects from drinking water at Kelly Air Force Base (AFB) on-base Wells 313 and 314. The Agency for Toxic Substances and Disease Registry (ATSDR) prepared this health consultation in response to the Kelly AFB Installation Restoration Advisory Board's concerns about a connection between Well 313 and the contaminated shallow aquifer. Well 314 was also a concern because it was connected to Well 313. Details of the wells, the sampling, and discussion of the public health implications are provided in the next four sections.

ATSDR concludes that past exposure from ingestion of water from Well 313 and Well 314 is not likely to result in adverse health effects. This conclusion is based on a review of the known toxicology and data on human exposures to the chemicals found in the water. Given the levels of the substances that were detected and the estimated duration of exposures, no adverse health effects are expected to be observed.

This consultation is Phase III of a three-phase process for evaluating potential human exposures and possible health effects from chemicals released into the environment at Kelly AFB. Phase III is divided into two parts: this health consultation and a public health assessment for East Kelly. The East Kelly assessment is being completed as a separate document. Phase I of this process was completed on August 20, 1999, with issuance of the public health assessment for Kelly AFB. Phase II addresses past and current air emissions and health outcome data and the evaluation will be presented in three separate documents.

This Health Consultation was released for public comment on June 1, 2001. Only the U.S. Air Force (USAF) submitted written comments. Their comments and ATSDR's responses appear in Appendix E. Subsequently, two independent experts reviewed this document. Their comments and ATSDR's responses appear in Appendix F.

BACKGROUND

The following pertinent environmental conditions and existing data are presented and discussed in this section.

- The groundwater below Kelly AFB
- Groundwater contamination in the shallow aquifer
- On-base drinking water supply and distribution system
- Groundwater from the shallow aquifer flowing into Well 313

Groundwater below Kelly AFB

Groundwater below Kelly AFB is found in two main geologic zones (see Figure 1). These zones are called the *shallow aquifer* and the *Edwards Aquifer*. The top of the shallow aquifer is found 3- to 37-feet below ground surface (bgs) across Kelly AFB, with depths ranging from 0 to 20 feet. The shallow aquifer generally exists as an unconfined water table aquifer, meaning that water can flow freely from the ground surface into the shallow aquifer. Below the shallow aquifer, seven different layers of clay and rock prevent the shallow aquifer water from going deeper into the ground.

The second main water-bearing zone below Kelly AFB is the Edwards Aquifer. Below Kelly AFB, the Edwards Aquifer is approximately 1,500 feet bgs and slopes to the surface northwest of San Antonio in an area known as the Balcones fault zone. Water enters (recharges) the Edwards Aquifer in the Balcones fault zone via runoff from rain and from the bottom of rivers (CH_2M Hill 1996). Under natural conditions, the Edwards Aquifer is not connected to the shallow aquifer below Kelly AFB. Hence, surface water does not naturally flow into the Edwards Aquifer below Kelly AFB (Appendix D).

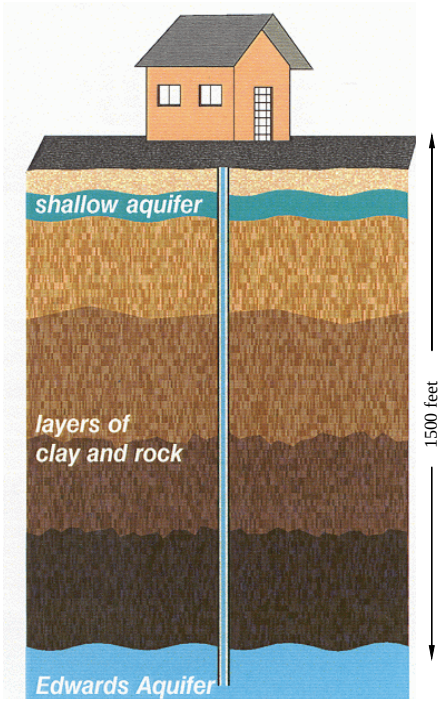

Figure 1. Simplified view of geology below Kelly AFB.

The Edwards Aquifer is the source of water for about 1.3 million people (as of 1997) in and near San Antonio and for ranches and farms in the region. The aquifer yields large quantities of water to wells and springs (United States Geological Survey 1997). The San Antonio metropolitan area is one of the largest cities in the United States to rely on groundwater (mainly from the Edwards Aquifer) for its principal water source.

According to the Texas Water Development Board's well database (February 2000), Bexar County has 1,116 wells and springs, not including Kelly AFB's monitoring wells (Figure 2). Of these, 1,057 are used as a water source and 59 are used for oil or gas exploration or extraction, development or operation of mines, or monitoring groundwater**.** The 1,057 wells and springs supply water to several kinds of users, including commercial, domestic, agricultural, industrial, medicinal, public, aquaculture, stock, and institutional. Of these, 943 tap into the Edwards Aquifer, and 114 tap into the shallow aquifer or deeper geologic zones. While this well inventory does not contain all of Kelly AFB's current or past drinking water or irrigation wells (the inventory is not 100% complete), it illustrates the widespread use of the Edwards Aquifer in Bexar County.

On-Base Drinking Water Supply and Distribution System

Kelly AFB has twenty-one wells that tap into the Edwards Aquifer currently or in the past (SAIC 1996, 1997; Griffith [no date]). Twelve of these wells, including Wells 313 and 314, are used or

have been used for drinking water and industrial production; six are currently active (Tables 1 and 2). The other nine wells have been used principally for irrigation. Wells 313 and 314 were constructed in 1910 and 1940 and permanently sealed in 1991 and 1998, respectively.

The drinking water supply wells feed into a closed distribution system consisting of tanks, pumps, and pipes. The water is used exclusively for the base, both military and civilian personnel. It services on-base housing, industrial processes, operations, and office buildings. From 1981 through 2000, the water served a total of 33,000 civilian workers and a residential on-base population that ranged from about 1,802 to 2,675 (children under 5 ranged from 151 to 257; see Appendix F, Tables 1 and 2). The water was used for drinking, bathing, and cleaning in residential and industrial areas of the base. Exposure would have been through oral intake, inhalation if the contaminants volatilize during use, and dermal contact.

The wells in the distribution system have been analyzed for volatile organic compounds (VOCs) since 1983 under the Safe Drinking Water Act (Table 3). From 1983 to 1998, only Wells 313 (twice) and 1044 (once) exceeded screening values and MCLs for drinking water. The screening values are modified EPA Region 6 screening values and include exposure via ingestion and incidental inhalation (Appendix A, dermal contact was not included in the screening values because risk from dermal absorption is 10 times or more below the risk from inhalation and ingestion and not considered significant). Well 313 exceeded the screening value once in 1986 for 1,2-dichloroethane at 43 μg/L and chloroform at 12 μg/L and once for the MCL in 1988 for tetrachloroethylene (PCE) at 5.5 μg/L (the MCL was not in effect until July 30, 1992 but is used here as a screening value). Tables 4, 5, and 6 provide individual sample results for Wells 313, 314, and 1044. Well 1044 exceeded the screening value and MCL once in 1986. For this health consultation, ATSDR only focused on Wells 313 and 314 as requested by the Kelly AFB Installation Restoration Advisory Board. Well 1044 is discussed further in Appendix B.

Before 2001, the wells at Kelly AFB were owned and operated by Kelly AFB. In July 2001, Kelly AFB was closed and realigned for reduced military uses and private commercial and industrial development. The San Antonio Water System became the new owners and operators of the Kelly AFB wells in December 2000.

Groundwater contamination in the shallow aquifer

Water in the shallow aquifer below Kelly AFB is contaminated with chemicals from Kelly AFB and possibly other sources. The contamination from Kelly AFB is the result of past spills and releases of solvents, fuels, and other organic chemicals. The area around the base is or was used for farms, automotive repair shops, dry cleaners, paint shops, and various industries. The shallow aquifer is considered to be the most likely source of contamination to Well 313 because a leak was discovered in 1989 in a pipe attached to the well casing. This leak allowed water from the shallow aquifer into Well 313.

Under the Department of Defense Installation Restoration Program (IRP), Kelly AFB investigated the shallow groundwater contamination by dividing the base into five zones. Wells 313 and 314 are located in Zone 3. In this zone, Kelly AFB installed 214 monitoring and

temporary wells to determine the nature and extent of contamination (Figure 3). Data from two monitoring wells located within 50 feet of Wells 313 and 314 and others in the vicinity indicate that groundwater near Wells 313 and 314 contain PCE at 100 micrograms per liter (μg/L) and trichloroethylene (TCE) at 10 μg/L (Figure 3). ATSDR used the data from the IRP monitoring wells in the following exposure assessment discussion as a worst case scenario. The highest concentrations of PCE and TCE in these wells were 5.5 μg/L and 2.8 μg/L, respectively, in Well 313 and <0.5 μg/L and <0.5 μg/L, respectively, in Well 314 (Table 3).

ATSDR reviewed the results of groundwater sampled for metals and found that metals were not a health hazard. In 1986, mercury was detected at 2.5 μg/L in Well 141. The EPA's maximum contaminant level (MCL) for mercury is 2 μg/L. The sampling in 1986 also found lead at 43 μg/L in Well 141; EPA's action level for lead is 15 μg/L. However, Well 141 is not a point of exposure because it had been out of service since 1984.

Groundwater from the shallow aquifer flowing into Well 313

Well 313 had been taken out of service in January 1989, but in June of that year, base personnel discovered water running into the well from a horizontal pipe. One day after this discovery, Kelly AFB sampled the running water for PCE only. The results showed PCE at 52 μg/L.

Three days after this discovery, Kelly AFB installed a temporary plug in Well 313 to seal off the horizontal pipe. Well 313 was sealed permanently in 1991. Well 314, connected to the other end of the horizontal pipe, was permanently sealed in 1998. Kelly AFB did not find water running into Well 314 from the pipe. A history of Wells 313 and 314 appears in Table 7.

The designs of Wells 313 and 314 and relative water levels between the shallow and Edwards Aquifer are important for determining how long the contaminated water could have been flowing into Well 313. Well designs before the 1970s show that the two wells, 30 to 50 feet apart, were connected by a horizontal pipe (Figure 4). The water pumps were located in the horizontal pipe. The artesian conditions of the Edwards Aquifer pushed the water from the deep Edwards Aquifer up to the horizontal pipe and to the pumps. The pumps then pushed the water into the distribution system. Sometime during the 1970s, new pumps in the deeper portion of each well replaced the old pumps (Figure 5). At this same time, plugs were installed in the horizontal pipe. The new pumps then pumped water from the wells into the distribution system, bypassing the sealed, obsolete horizontal pipe.

Under natural conditions, the water from the shallow aquifer is not connected to the Edwards Aquifer. However, if a leak occurred in the horizontal pipe, a connection could have developed allowing water to flow between the well and the shallow aquifer. The direction of the flow would depend on the relative water levels of the shallow aquifer and the Edwards Aquifer. If the well water level from the Edwards Aquifer was below the water level of the shallow aquifer, water from the shallow aquifer would leak into the horizontal pipe and the Edwards Aquifer well (Figure 6). Conversely, if the well water level from the Edwards Aquifer were above the water level of the top of the shallow aquifer, water from the Edwards Aquifer well would leak into the shallow aquifer (Figure 7). The amount of flow is discussed in the next section.

The Edwards Aquifer water level at Kelly AFB rises and falls based on the amount of recharge and the amount withdrawn. Similarly, the water level in the shallow aquifer also rises and falls with time, based on the amount of rainfall and the amount of water withdrawn by wells or discharged to creeks. For the shallow aquifer, water level data is available from Kelly AFB from the two IRP monitoring wells near Wells 313 and 314 (Figure 3). For the Edwards Aquifer, water level readings are available from the San Antonio Water System (SAWS) Edwards Monitoring Well No. J-17 and other wells in the Texas Water Development (TWD) database.

Historic water level readings from Wells 313 and 314 are not available. To approximate them, ATSDR reviewed data from the TWD database for private well No. AY6844214 because of its close proximity to Kelly AFB (Figure 2). From this data, however, ATSDR found that the water levels in the SAWS well J-17 and well AY6844214 do not correlate over time (Figure 8), probably because water flow in the Edwards Aquifer is not evenly distributed. Therefore, ATSDR cannot use data from either well to determine the water levels in Wells 313 and 314. As a result, ATSDR did not deduce an exposure duration based on water level data. Instead, ATSDR derived exposure durations based on the well sampling data discussed in the next section.[1]

DATA EVALUATION AND INTERPRETATION

In this section, data from the Background section is used to formulate exposure levels and durations. The results are then compared to health screening levels.

When did contamination first appear in Wells 313 and 314 and how long did the contamination last?

Wells 313 and 314 were first sampled and analyzed for VOCs in November 1983. At that time, VOCs were not detected in Well 313 and one VOC (1,4-dichlorobenzene) was detected in Well 314 (Tables 3 and 4). Tests first detected VOCs (1,2-dichloroethane, chloroform, methylene chloride, PCE, 1,1,1-trichloroethane, and TCE) in Well 313 in January 1986.

Kelly AFB reported that the samples taken in January 1986 under the IRP monitoring program were erroneous. The base sampled Wells 313 and 314 five more times in 1986 and found that the last samples, collected in May, did not contain compounds above detection limits. The base concluded that the errors were the result of improper cleaning of equipment after the equipment was used to sample the IRP monitoring wells. Even so, for the purposes of this health consultation, ATSDR assumed that the results in January 1986 were correct and proceeded to use these measured concentrations to estimate potential exposure dosage.

[1] In response to peer review comments, ATSDR calculated an exposure duration based on the water levels in well J-17 (see Appendix F, Question 5). Using water levels, however, resulted in a shorter exposure duration of about 3 years for the time period of 1960 to when the well was closed in 1989. In the interest of protecting public health, ATSDR elected to use the more conservative scenario of a longer duration based on the well sampling data.

1,4-dichlorobenzene was detected in Well 314 at 75 μg/L in 1983. The Safe Drinking Water Act Maximum Contaminant Level (MCL) is also 75 μg/L. 1,4-dichlorobenzene was not detected again in Well 314 through 1998 (the last date ATSDR evaluated), a period of 16 years. 1,4-dichlorobenzene was never detected in Well 313. These results indicate that this chemical is not a likely contaminant of the Edwards Aquifer and not a health hazard.

Another factor in determining when contamination first appeared is when the leak in the horizontal pipe first occurred. Unfortunately, this information is not available. Therefore, ATSDR assumed for Well 313 that the exposure duration was six years (just after the well was sampled in 1983 with no detected VOCs to January 1989, when the well was closed). For Well 314, sampling in February 1990 and thereafter did not detect VOCs. Therefore, the maximum duration of exposure from Well 314 would be about six years (from just after the well was sampled in November 1983 with one detected VOC at the MCL until February 1990).

The exposure duration estimates could underestimate actual exposure if the samples in 1983 are not representative of water quality prior to this time. The water quality could be affected by the water levels of the shallow and Edwards Aquifer which are not precisely known below Kelly AFB prior to 1983. Using historical water levels of Edwards Aquifer well J-17, however, indicates that six years of exposure is a worst case scenario.

What contaminants and what concentrations were found in Wells 313 and 314 and the horizontal pipe?

Testing of water from Well 313 detected 1,2-dichloroethane, benzene, chloroform, methylene chloride, PCE, and TCE (Table 4). Of these chemicals, 1,2-dichloroethane (43 μg/L) and chloroform (12 μg/L) were the only compounds detected above the screening levels. A test detected PCE once in 1988 at 5.5 μg/L, which is above EPA's MCL of 5 μg/L but below the adjusted EPA Risk Based Concentration (RBC) screening value (adjusted for 6-years of exposure, MCLs assume lifetime exposures).

Testing of water from Well 314 detected benzene, chloroform, ethylbenzene, methylene chloride, 1,1,1,2-tetrachloroethane, and 1,1,2-trichloroethane. None of these chemicals exceeded the screening levels or MCLs (Table 5).

Of the contaminants that exceeded the screening levels, what concentrations were people exposed to?

Chloroform, 1,2-dichloroethane, and tetrachloroethylene were the only compounds that exceeded the screening values or MCLs in Wells 313 and 314. Therefore, ATSDR determined the concentrations of these chemicals in the water as it reached the faucets.

Neither Kelly AFB nor the State of Texas sample water from faucets in offices and on-base housing for VOCs. Sampling for VOCs occurs only at the wells. Therefore, ATSDR used two

approaches to calculate the VOC concentrations to which people were exposed. First, ATSDR used the VOC concentrations detected in 1986 and 1988 (12 μg/L chloroform, 43 μg/L 1,2-dichloroethane and 5.5 μg/L PCE) in Well 313 and calculated the concentrations after mixing with water from Well 314. Water pumped from Well 313 and Well 314 was mixed together before distribution.

ATSDR used the annual well production volumes for 1984 (1984 data were used because they resulted in the highest calculated concentrations for comparison; see Table 8) and assumed the concentration in Well 314 was at detection level to determine that the water would have been distributed at a concentration of 7.8 μg/L chloroform, 26.8 μg/L 1,2-dichloroethane, and 3.8 μg/L PCE (Appendix C-1). These concentrations would be reduced as the water combined with water in the distribution system from other production wells. Based on this first dilution, chloroform and PCE would be reduced below MCLs and screening values, while the concentration of 1,2-dichloroethane would be four times above the screening value and five times above the MCL.

Well 313 was sampled once in 1983 with a result of "not detected" for 1,2-dicloroethane. This chemical was detected only in 1986, when Well 313 was sampled five times in four months. Two of these samples were collected on January 22, 1986. One sample detected the chemical at 43 μg/L; the second sample did not detect it at all. In March 1986, 1,2-dichloroethane was detected at 3 μg/L and 2.1 μg/L, but not detected in an April 1986 sample. On the basis of these inconsistent results, ATSDR determined that the 43 μg/L result was not a representative value for water from Well 313.

Even if the 43 μg/L had been a representative value, the water from Well 313 would have been mixed with water from Well 314, diluting the concentration to 26.8 μg/L before it entered the water distribution system. Furthermore, a person exposed to this diluted concentration would have been exposed for a relatively short duration—the sampling data suggests about 28 months. Whereas EPA's cancer screening values are for a total lifetime of exposure of 30 years, ATSDR used modified screening values for 1,2-dichloroethane, on the basis of the six-year exposure scenario discussed earlier, of 6 μg/L for cancer and 17 μg/L for noncancer health effects. For an adult exposed for 28 months via ingestion and incidental inhalation (e.g., inhaling the VOC volatilizing from the water while showering), the adjusted screening value for cancer would be 15 μg/L. For ingestion alone, the value for 28 months of exposure would be 50 μg/L at 1 in 100,000 risk. A child's cancer risk from using water containing 26.8 μg/L 1,2-dichloroethane for 28 months is 1.6×10^{-5} (exposure via ingestion and incidental inhalation) which is slightly above ATSDR's "No Apparent Increase Risk" cancer category (Appendix A, this category applies to adults also since a child's risk is greater).

Therefore, cancer from exposure to 1,2-dichloroethane from Well 313 water is not likely for the following reasons:

- The 43 μg/L is not a representative number—concentrations were likely 10 times lower

- Even if 43 μg/L were a representative value, this concentration would have been diluted to 26.8 μg/L after mixing with water from Well 314, and this concentration is close to the adjusted screening values (both with and without inhalation exposure).
- The calculated cancer risk is only slightly above the threshold for ATSDR's "No Apparent Increase Risk" category.

ATSDR also reviewed the noncancer effects of 1,2-dichloroethane. The noncancer screening value[1] used by EPA Region 6 for 1,2-dichloroethane is based on a reference dose that has been withdrawn (2.9×10^{-3} mg/kg/day)(EPA 2002). EPA Region 9's noncancer screening value for 1,2-dichloroethane has not been withdrawn and is based on a reference dose that is 10 times larger for ingestion (i.e., less toxic, 3×10^{-2} mg/kg/day). ATSDR's minimal risk level (MRL) for intermediate exposure (less than one year, 0.2 mg/kg/day) is 100 times larger than EPA Region 6's reference dose. ATSDR's reference dose translates to concentrations of 2000 μg/L for children and 7000 μg/L for adults. Hence, even if water from Well 313 did contain 1,2-dichloroethane at 43 μg/L, no apparent public health hazard would exist because the concentration was low and was for a short duration (six years or less as explained on page 6).

ATSDR's second method was to calculate potential VOC concentrations in the tap water based on VOC concentrations leaking into Well 313 from the shallow aquifer. This approach factored contaminant concentrations leaking into the pipe, how much water was leaking into the pipe, the concentrations in the Edwards Aquifer, and the proportion of water coming from the Edwards Aquifer.

The contaminant concentration in the water from the horizontal pipe was measured at 52 μg/L of PCE (no other VOCs were analyzed for). As discussed in the previous section, the PCE and TCE concentrations could have been as high as 100 μg/L and 10 μg/L respectively in the shallow aquifer. 1,2-dichloroethane was not detected in the IRP monitoring wells adjacent to Wells 313 and 314 and was not analyzed in this approach. The highest concentration of chloroform detected in the IRP monitoring wells was 8 μg/L which is equal to the screening value and hence, not analyzed in this approach since dilution would reduce the concentration to levels below concern. ATSDR included TCE in this analysis because the concentration in the shallow aquifer exceeds the MCL.

[1] MCLs or maximum contaminant levels are the highest levels of a contaminant allowed in drinking water based on federal law. MCLs are based on a lifetime of exposure. MCLs are a useful benchmark for determining if a health risk exists. In evaluating exposure to contaminated drinking water at Kelly AFB, however, ATSDR concluded that a 6-year exposure period was more likely than a lifetime exposure. Therefore, ATSDR created a screening value based on this shorter exposure period and U.S. EPA Region 6 Human Health Screening Values. In the text, concentrations are compared to MCLs and screening values for comparison and evaluation. ATSDR is also a source of screening values but they are less conservative (higher concentrations) than U.S. EPA Region 6 values for the chemicals evaluated in this report and hence, not used. Region 6 screening values for water include exposure via ingestion of the water and incidental inhalation from volatilization (e.g. vapors offgasing from the water during showering).

The rate of water entering the pipe from the shallow aquifer has not been measured, but can be derived from the following information:[1]

- Kelly AFB is pumping groundwater from the shallow aquifer for treatment. Pumping rates vary from 1.2 to 50 gallons per minute (gpm).

- The shallow groundwater is moving toward and discharging into Leon Creek. The rate at which this groundwater is moving provides information about how much water could flow into the horizontal pipe. The flow rates into Leon Creek range from 0.045 gpm to 1392 gpm (CH_2M Hill 1999). These rates include the total amount of water over the entire 14,755 feet of Leon Creek as it passes through Kelly AFB. This equates to 0.047 gpm to 0.0000015 gpm per foot per side of Leon Creek.

From these numbers, the potential amount of water entering the pipe could be as much as 50 gpm (theoretical maximum) or as low as 0.0000015 gpm. If 50 gpm is used (based on the pumping rate), one must consider that this flow rate is the cumulative flow rate from the entire well screen. If one assumes a 10-foot well screen, the flow rate is about 5 gpm per foot of screen length. This value does not include the possibility of the screen being exposed to the unsaturated zone because the cone of depression would increase the flow rate per foot of screen length. It also does not consider the total exposed surface area of the screen. For example, a one-ft section of screen with a 2-inch diameter would have an exposed surface area of about 0.5-sq. ft. This area is equivalent to a hole in the horizontal pipe 8.6 inches by 8.6 inches (this calculation assumes that the screen is completely open; in reality, a portion of the screen consists of solid material not open for transmission of water).

Assuming that the leak in the horizontal pipe is similar to two feet of screen length in the pipe, 10 gpm is flowing into the pipe (5 gpm/ft times 2). Using 10 gpm containing a concentration of

[1]After this document was published for public comment, two Kelly AFB-funded studies evaluated the potential for shallow aquifer water contaminating the Edwards Aquifer through faults and fractures or through improperly installed or damaged wells. The studies concluded that fault and fractures are not likely to be a source of flow between the two aquifers. In regards to wells, the first document (Hovorka et al 2002) estimated water flow from the shallow aquifer to the Edwards Aquifer through a damaged or improperly installed well in two ways. The first method estimated the potential flow rate of the well as an open pipe. The flow ranged from 42 gpm at one ft of head and a 4-inch pipe to 3,960 gpm at 20 ft of head and a 12-inch pipe. This approach assumes an unlimited and constant flow of water to the pipe, which is not realistic.

The second method included the transmissivity properties of the aquifers. The predicted flow rate then ranged from 0.05 gpm with a 4-inch diameter well and 1 foot of head to 1,418 gpm with a 12-inch diameter well and 20 ft of head. The lower ranges of this second method are similar to the 50 gpm estimated by ATSDR in this document

The second of the two new reports funded by Kelly AFB was a review of the Hovorka report (Miller 2003). This report concluded that the flow estimates in the Hovorka report are “unrealistically high,” but Miller (2003) did not provide a revised estimate of the flow. ATSDR’s range of flow estimates seem more realistic since the modeled concentrations are close to the measured concentrations for PCE (see table on the following page).

100 μg/L PCE and 10 μg/L TCE (the highest concentrations measured in the surface aquifer near Wells 313 and 314), combining with water from the Edwards Aquifer with concentrations at the detection level of 1 μg/L, the concentration of water coming out of Well 313 would be 3.26 μg/L PCE and 1.21 μg/L TCE (Appendix C).[1]

If 50 gpm is used as the amount of water entering Well 313 from the horizontal pipe, the concentration of water coming from Well 313 would be 12.3 μg/L PCE and 2.03 μg/L TCE. Mixing this water from Well 314, the concentrations would be 5.57 μg/L for PCE and 1.42 μg/L for TCE. These values are below the cancer health screening values of 55 μg/L PCE and 80 μg/L TCE (see Table 3). The value of 5.57 μg/L PCE is slightly above the MCL[1], but it is based on the 50 gpm of water entering the horizontal pipe, which is a high end estimate. The MCL is also based on a lifetime of exposure while actual exposure was relatively shorter in duration. The PCE value is 10 times below the modified EPA RBC value. Therefore, exposure to PCE is not likely to pose a health hazard.

The drinking water exposure concentrations from these scenarios are summarized in the following table:

Chemical	**Maximum VOC concentrations detected in Wells 313 and 314 and subsequent mixing of water from these two wells** (μg/L)	**Maximum VOC concentrations in shallow aquifer leaking and mixing with water from Well 313 and then with Well 314** (μg/L)		**Screening Value** (μg/L)	
		10 gallons per minute leakage rate	**50 gallons per minute leakage rate**	MCL	Modified EPA RBC‡
Chloroform	7.8	Not analyzed*		80†	8c 61nc
1,2-dichloroethane	26.8§	Not detected in shallow aquifer		5	6c 17nc
Tetrachloroethylene (PCE)	3.8	3.26	5.57	5	55c 250nc
Trichloroethylene (TCE)	Not detected	1.21	1.42	5	80c 35nc

* Not analyzed because the maximum concentrations were below the MCL and equal to the modified EPA Region 6 Risk Based Concentration (RBC) in the shallow aquifer.
†No MCL exists for chloroform. This MCL is for trihalomethanes, which consist primarily of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
‡ The EPA Region 6 Risk Based Concentration (RBC) value of 0.12 (μg/L) was modified from 30 years to 6 years of exposure and from a risk of 1 in 1,000,000 to 1 in 100,000 and includes exposure via ingestion and inhalation.
§ This is equivalent to 1.6×10^{-5} cancer risk based on exposure to a child for 28 months via ingestion and incidental inhalation (e.g. inhalation of vapors offgassing from the water during showering).

[1] These calculations use the 1983 production data because it produced the highest concentrations for comparison.

To summarize, the calculated concentrations in these scenarios are below the screening values except for 1,2-dichloroethane and PCE. As explained previously, these two chemicals are not likely to pose a health hazard.

CHILD HEALTH CONSIDERATIONS

As part of this health consultation, ATSDR considered the unique vulnerabilities of infants and children exposed to environmental contamination and hazards. Children could be present in on-base housing and exposed to the water.

Water from Well 313 and Well 314 was mixed together and put into the distribution system. The water in the distribution system was further mixed with water from other wells. ATSDR considered this mixing and levels of exposure to children in this consultation.

CONCLUSION

Based on our calculated concentrations, flow rates from the horizontal pipe, and assumptions presented in the previous section, ATSDR concludes that the water entering Well 313 from the horizontal pipe did not contaminate the drinking water at levels of public health concern. High-end estimates indicate that the concentration could possibly have been above MCLs, but such concentrations are very unlikely. Concentrations measured in Wells 313 and 314 were not reproducible and were not consistent. If a chemical was present, the reported concentration was below levels of health concern and present for a relatively short time (from one year to six years). ***Hence, past exposures from potable use of water from Well 313 and 314 were not likely to result in adverse health effects. Because some exposures may have occurred, although at low levels, ATSDR categorizes this pathway as a no apparent public health hazard.***

RECOMMENDATIONS

ATSDR does not have any recommendations at this time.

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Table 1. Production/Drinking Water Well Information, Kelly Air Force Base.

New Well Number (Same as Building Number)	Old Base Well Number	"I" Series Well Number	USGS Well Number	Year Drilled	Date Plugged	Total Depth (feet)	Max* (gpm)	Production for 7/88 (1000 gallons)	Comments
81	–	–	–	1994	na	1,500	2,200	0	Replacement for wells 141 and 313.
141	3	96	810	1906	6/20/91	1,400	900	0	Out of service since 1984.
313	2	124	808	1910	6/26/91	1,590	1,050	36,535	7/7/88: 5.5 μg/L PCE detected. 9/23/88: No VOCs detected. 1/31/89: Well 313 taken out of service. 6/23/89: Horizontal pipe found with 52 μg/L PCE. 7/17/89: Gap in well at 590 feet. 3/26/91: Determined pipe comes from shallow aquifer. 6/26/91: Plug placed in pipe over horizontal pipe. 6/16/91: Well 313 is cemented and permanently sealed.
314	4	97	809	1940	6/21/98	1,608	1,500	28,289	7/7/88, 8/11/88, 9/23/88, 7/14/89, 9/6/89, 10/12/89: No contaminants detected. 2/1/90: Detected very low levels of chlorinated solvents. 3/6/90: Horizontal pipe found. 4/11/90: A patch is placed over the horizontal pipe as a precaution. 6/21/98: Well is cemented and sealed.
1040	–	–	–	1996	na	1,560	800	0	Replacement for well 1044.
1044	7	66	713	1924	12/19/96	1,677	550	13,627	Well plugged and replaced by well 1040.
1536	8	77	–	1943	na	1,042	650	13,338	--
1556	6	78	806	1943	1/23/97	1,030	700	15,024	Well plugged and replaced by well 2047.
1638	5	123	805	1940	na	1,632	1,600	12,864	--

Table 1. Production/Drinking Water Well Information, Kelly Air Force Base (continued)

New Well Number (Same as Building Number)	Old Base Well Number	"I" Series Well Number	USGS Well Number	Year Drilled	Date Plugged	Total Depth (feet)	Max* (gpm)	Production for 7/88 (1000 gallons)	Comments
1761	–	–	–	not known	na	1,460	1,500	0	Under design. Replacement for well 314.
2047	–	–	–	–	na	505	2,200	0	Replacement for wells 314 and 1556.
3010	–	–	–	1919	na	1,120	1,300	6,327	--

*Abbreviations
gpm = gallons per minute
na = not applicable
μg/L = micrograms per liter
Max = maximum potential production in gallons per minute

Note: The production wells draws water from the Edwards Aquifer. All production wells feed into a closed-loop distribution system. The water is used exclusively for the base—both military and civilian personnel. Since 1983, the base's population has ranged from a low of 19,021 in 1995 to a high of 24,830 persons in 1999, with 21,961 persons in 1988. Information compiled by Air Force personnel suggests that the average stay on base is approximately two years for officers and three years for enlisted personnel. The *average stay* refers to members of the military stationed at Kelly AFB. Members of the military may be living on base or off base. These average stays do not apply to civilian personnel, who work on base but do not live on base. Civilians could have worked at Kelly AFB their entire careers. Length of employment for civilian personnel at Kelly AFB has ranged up to 30+ years (see Appendix F-1). ATSDR assumed that civilians and military would consume their entire daily requirements of water from the water distribution system at Kelly AFB regardless if they lived on or off base. In reality, non-military would consume only a fraction of their daily water intake at the base.

Table 2. Irrigation Wells at Kelly Air Force Base.

"I" Series Well Number	Year Drilled	Date Plugged	Comments
65	1912	See Comment	Inactive and abandoned. Kelly AFB could not locate this well, and records do not exist. May be covered by Taxiway 3B.
69	1924	1996	--
72	Possibly in the 1930s	1997	--
73	1933	1997	--
74	Unknown	1998	--
75	Early 1930s	Unknown	Abandonment confirmed by Kelly AFB in 1996
76	1913	Unknown	Abandonment confirmed by Kelly AFB in 1996.
80	<1934	Unknown	Abandonment confirmed by Kelly AFB in 1996.
99	1912	1996	--

Table 3. Production/Drinking Water Well Monitoring Data (1983–1998)[*], Volatile Organic Compound Concentration by Production Well, Kelly Air Force Base

Chemical	Well 141	Well 313	Well 314	Well 1044	Well 1536	Well 1556	Well 3010	Well 1638	EPA MCL or LTHA (µg/L)	EPA RBCs (Six Years of Exposure at 1/100,000) (µg/L)
1,2-Dichloroethane	0.3–4.2 (2/6)	3–**43** (3/9) [**1/3]**	nd (0/10)	2.3–**36**(2/12) **[1/2]**	nd (0/11)	3.5–4 (2/8)	4.5 (1/12)	nd (0/11)	5	6 c 17 nc
1,3-Dichlorobenzene	nd (0/6)	nd (0/9)	nd (0/9)	**305** (1/12) **[1/1]**	nd (0/11)	nd (0/8)	nd (0/12)	nd (0/11)	600 LTHA	17 nc
1,4-Dichlorobenzene	nd (0/6)	nd (0/9)	nd (0/9)	**149** (1/12) **[1/1]**	nd (0/11)	nd (0/8)	nd (0/12)	nd (0/11)	75	24 c 1400
Benzene	nd (0/6)	3.87 (1/9)	3.37 (1/11)	0.5–3.58 (2/12)	4.22 (1/11)	3.43 (1/8)	3.72 (1/12)	5.74 (1/11)	100	21 c 11 nc
Chlorobenzene	nd (0/6)	nd (0/9)	nd (0/11)	**435** (1/12) **[1/1]**	nd (0/11)	nd (0/8)	nd (0/12)	nd (0/11)	no value	39 nc
2-Chloroethylvinyl ether	nd (0/6)	nd (0/7)	nd (0/7)	0.3 (1/7)	nd (0/6)	nd (0/6)	nd (0/7)	nd (0/5)	3540[†]	no value
Chloroform	0.4–3.8 (3/6)	1–**12** (2/9) **[1/2]**	nd (0/11)	1–6.7 (2/13)	0.3–4.5 (2/12)	1.4–21 (1/9)	1.7–**10**(3/12) **[1/3]**	2.7–**16** (3/11) **[1/3]**	700	8 c 61 nc
Ethylbenzene	nd (0/6)	nd (0/9)	nd (0/11)	39 (1/12)	nd (0/11)	nd (0/8)	nd (0/12)	nd (0/11)	5	1300 nc

Table 3. Production/Drinking Water Well Monitoring Data (1983–1998)[*], Volatile Organic Compound Concentration by Production Well, Kelly Air Force Base (continued)

Chemical	Well 141	Well 313	Well 314	Well 1044	Well 1536	Well 1556	Well 3010	Well 1638	EPA MCL or LTHA (μg/L)	EPA RBCs (Six Years of Exposure at 1/100,000) (μg/L)
ethylene chloride	0.5–1.6 (2/6)	0.5–5 (2/9)	2.1 (1/9)	1.1–3.8 (2/11)	1.7–2.3 (2/10)	1.3–1.4 (2/8)	1.3 (1/11)	2.4 (1/11)	5	215 c 1600 nc
1,1,1,2-Tetrachloroethane	0.08 (1/6)	nd (0/9)	4.7 (0/9)	nd (0/12)	nd (0/11)	nd (0/8)	nd (0/11)	nd (0/11)	no value	21.5 c 180 nc
Tetrachloroethylene	nd (0/6)	0.12–5.5 (4/9)	nd (0/10)	0.2 (1/13)	nd (0/7)	nd (0/7)	nd (0/8)	nd (0/6)	5	55 c 250 nc
1,1,1-Trichloroethane	1.8 (1/6)	1.2 (1/9)	2.7 (1/11)	nd (0/12)	2.5-2.6 (2/11)	1–1.8 (3/8)	2 (1/11)	2.5 (1/11)	200	790 nc
1,1,2-Trichloroethane	nd (0/6)	nd (0/9)	0.6 (1/9)	nd (0/12)	nd (0/11)	nd (0/8)	nd (0/11)	nd (0/11)	5	10 c 24 nc
Trichloroethylene	nd (0/6)	nd –2.8 (2/9)	nd (0/10)	2.2 (1/13)	nd (0/7)	nd (0/6)	nd (0/8)	nd (0/5)	5	80 c 35 nc

Table 3. Production/Drinking Water Well Monitoring Data (1983–1998)[*], Volatile Organic Compound Concentration by Production Well, Kelly Air Force Base (continued)

Notes:

* Data collected by OEHL (11/23/83, 4/15/85, 1/22/86, 3/11/86, 5/15/86); Radian (1/22/86, 4/16/86); TDH (7/7/88, 12/01/93, 3/24/94, 7/8/94, 12/03/96, 11/0-3/97); and LCRA (8/14/94, 11/30/95); TWC (12/01/93); TNRCC (2/12/98).

† No human health based screening levels were available for 2-chloroethylvinyl ether. This figure is the surface water screening value derived by U.S. EPA Region 4 Water Management Division. It was obtained from Water Quality Criteria documents and represents the chronic ambient water quality criteria values for the protection of aquatic life.

Key:

c = cancer
nc = noncancer
EPA RBCs = EPA Region 6 Risk Based Concentrations based on 30 years of exposure 24 hours a day, 350 days per year, and exposure via ingestion and inhalation.
LCRA = Lower Colorado River Authority
LTHA = Lifetime Health Advisory for drinking water
MCL = EPA's maximum contaminant level
nd = not detected
OEHL= Occupational Environmental Health Laboratory
μg/L = micrograms per liter
TDH = Texas Department of Health
TNRCC = Texas Natural Resources and Conservation Commission
TWC = Texas Water Commission
(x/x) = number of detects/number of samples collected
[x/x] = number of detects above EPA Risk Based Concentration at six years of exposure at 1/100,000 risk/number of detects

Table 4. Production/drinking Water Well Monitoring Data (1983 -1988), Volatile Organic Compound Concentration for Well 313, Kelly Air Force Base

	Organization Collecting and Analyzing Sample with Month and Year of Sample (μg/L)										Screening Values	
	Sampling as part of the SDWA		Sampling as part of the IRP program				Sampling as part of the SDWA					
Chemical	**OEHL 11/83**	**OEHL 4/85**	**Radian 1/86**	**OEHL 1/86**	**OEHL 3/86**	**OEHL 3/86 (split)**	**OEHL 4/86**	**OEHL 5/86**	**TDH 7/88**	**TDH 9/88**	**EPA MCL or LTHA (μg/L)**	**EPA RBCs (6 Years of Exposure at 1/100,000) (μg/L)**
1,2-Dichloroethane	nd	ns	nd	**43**	3	2.1	nd	nd	<1.0	<1.0	5	6 c 17 nc
1,3-Dichlorobenzene	nd	ns	nd	nd	nd	nd	nd	nd	<1.0	<1.0	600 LTHA	17 nc
1,4-Dichlorobenzene	nd	ns	nd	nd	nd	nd	nd	nd	nd	<1.0	75	24 c 1400
Benzene	nd	ns	3.87	nd	nd	nd	nd	nd	<0.1	<0.1	100	21 c 11 nc
Chlorobenzene	nd	ns	nd	nd	nd	nd	nd	nd	<0.1	<0.1	no value	39 nc
Chloroform	nd	ns	nd	**12**	1	nd	nd	nd	<0.1	<0.1	700	8 c 61 nc
Ethylbenzene	nd	ns	nd	nd	nd	nd	nd	nd	<2.0	<.2.0	5	1300 nc
Methylene chloride	nd	ns	nd	5	0.5	nd	nd	nd	<0.1	<0.1	5	215 c 1600 nc
Tetrachloroethylene	nd	ns	0.34	0.6	nd	nd	0.12	nd	**5.5**	<0.1	5	55 c 250 nc
1,1,1-Trichloroethane	nd	ns	nd	nd	2.1	nd	nd	nd	<1.0	<1.0	200	790 nc
Trichloroethylene	nd	ns	nd	2.8	nd	nd	nd	nd	<0.1	<0.1	5	80 c 35 nc

Table 4. Production/drinking Water Well Monitoring Data (1983 -1988), Volatile Organic Compound Concentration for Well 313, Kelly Air Force Base (continued)

Source: Kelly AFB (no date)

Key:
c = cancer
nc = noncancer
EPA RBCs = EPA Region 6 Risk Based Concentrations based on 30 years of exposure 24 hours a day, 350 days per year, and exposure via ingestion and inhalation.
LTHA = Lifetime Health Advisory for drinking water
MCL = EPA's maximum contaminant level
nd = not detected
OEHL= Occupational Environmental Health Laboratory
μg/L = micrograms per liter
TDH = Texas Department of Health

Table 5. Production/Drinking Water Well Monitoring Data (1983–1998), Volatile Organic Compound Concentration for Well 314, Kelly Air Force Base

Chemical	Organization Collecting and Analyzing Sample with Month and Year of Sample (μg/L)															Screening Values	
	Sampling as part of the SDWA		Sampling as part of the IRP program						Sampling as part of the SDWA								
	OEHL 11/83	OEHL 4/85	Radian 1/86	OEHL 1/86	OEHL 3/86	OEHL 3/86 (split)	OEHL 4/86	OEHL 5/86	TDH 7/88	TDH 9/88	2/90*	TWC /93	TDH 3/94	TDH 12/96	TNRCC 2/12/98	EPA MCL or LTHA (μg/L)	EPA RBCs (Six Years of Exposure at 1/100,000) (μg/L)
1,2-Dichloroethane	<0.3	ns	nd	nd	nd	nd	nd	nd	<0.001	<0.001	nd	ns	<0.5	ns	<0.5	5	6 c 17 nc
1,3-Dichlorobenzene	ND	ns	nd	nd	nd	nd	nd	nd	ns	ns	nd	ns	<1.0	ns	<0.5	600 LTHA	17 nc
1,4-Dichlorobenzene	75	ns	nd	nd	nd	nd	nd	nd	nd	ns	nd	ns	<0.5	ns	<0.5	75	24 c 1400
Benzene	ND	ns	3.37	nd	nd	nd	nd	nd	<0.001	<0.001	nd	ns	<0.5	ns	<0.5	100	21 c 11 nc
Chlorobenzene	ND	ns	nd	nd	nd	nd	nd	nd	<0.001	<0.001	nd	ns	<0.5	ns	<0.5	no value	39 nc
Chloroform	ND	nd	nd	17	nd	nd	nd	nd	ns	<0.001	nd	ns	<0.5	ns	<0.5	700	8 c 61 nc
Ethylbenzene	ND	ns	nd	nd	nd	nd	nd	nd	<0.002	<0.002	nd	ns	<0.5	ns	<0.5	5	1300 nc
Methylene chloride	ND	ns	nd	nd	2.1	nd	nd	nd	ns	ns	nd	ns	<0.5	ns	<0.5	5	215 c 1600 nc
1,1,1,2-Tetrachloroethane	ND	ns	nd	nd	nd	nd	nd	nd	ns	ns	4.7	ns	ns	ns	<0.5	no value	21.5 c 180 nc
Tetrachloroethylene	<0.2	ns	nd	nd	nd	nd	nd	nd	<0.001	<0.001	nd	ns	ns	ns	<0.5	5	55 c 250 nc

Table 5. Production/Drinking Water Well Monitoring Data (1983–1998), Volatile Organic Compound Concentration for Well 314, Kelly Air Force Base (continued)

Chemical	Organization Collecting and Analyzing Sample with Month and Year of Sample (μg/L)															Screening Values	
	Sampling as part of the SDWA		Sampling as part of the IRP program						Sampling as part of the SDWA								
	OEHL 11/83	OEHL 4/85	Radian 1/86	OEHL 1/86	OEHL 3/86	OEHL 3/86 (split)	OEHL 4/86	OEHL 5/86	TDH 7/88	TDH 9/88	2/90*	TWC /93	TDH 3/94	TDH 12/96	TNRCC 2/12/98	EPA MCL or LTHA (μg/L)	EPA RBCs (Six Years of Exposure at 1/100,000) (μg/L)
1,1,1-Trichloroethane	nd	ns	nd	nd	2.1	nd	nd	nd	<0.001	<0.001	nd	ns	<0.5	ns	<0.5	200	790 nc
1,1,2-Trichloroethane	nd	ns	nd	nd	nd	nd	nd	nd	ns	ns	0.6	ns	ns	ns	<0.5	5	10 c 24 nc
Trichloroethylene	nd	ns	nd	nd	nd	nd	nd	nd	<0.001	<0.001	nd	ns	ns	ns	<0.5	5	80 c 35 nc

Notes:

* Organization collecting and analyzing sample not reported (Gargiulo 1998a).

Key: Source: Kelly AFB (no date).
c = cancer
nc = noncancer
EPA RBCs = EPA Region 6 Risk Based Concentrations based on 30 years of exposure 24 hours a day, 350 days per year, and exposure via ingestion and incidental inhalation.
LTHA = Lifetime Health Advisory for drinking water
MCL = EPA's maximum contaminant level
nd = not detected
OEHL= Occupational Environmental Health Laboratory
μg/L = micrograms per liter
TDH = Texas Department of Health
TNRCC = (Texas Natural Resources and Conservation Commission)
TWC = Texas Water Commission

Table 6. Production/Drinking Water Well Monitoring Data (1983–1995), Volatile Organic Compound Concentration (μg/L) for Well 1044, Kelly Air Force Base

Chemical	Organization Collecting and Analyzing Sample with Month and Year of Sample (μg/L)													Screening Values	
	Sampling as part of the SDWA		Sampling as part of the IRP program			Sampling as part of the SDWA									
	OEHL 11/83	Radian 1/86	OEHL 1/86	OEHL 3/86	OEHL 3/86 (split)	OEHL 4/86	OEHL 5/86	TDH 7/88	TDH 12/93	TDH 3/94	TDH 7/94	LCRA 8/95	LCRA 11/95	EPA MCL or LTHA (μg/L)	EPA RBCs (6 Years of Exposure at 1/100,000) (μg/L)
1,2-Dichloroethane	<0.3	nd	36	2.3	nd	nd	nd	<1.0	ns	<0.5	<0.5	<0.5	<0.5	5	6 c 17 nc
1,3-Dichlorobenzene	nd	nd	305	nd	nd	nd	nd	<1.0	ns	<1.0	<1.0	<0/5	<0.5	600 LTHA	17 nc
1,4-Dichlorobenzene	nd	nd	149	nd	nd	nd	nd	<1.0	ns	<0.5	<0.5	<0.5	<0.5	75	24 c 1400
Chlorobenzene	nd	nd	435	nd	nd	nd	nd	<0.1	ns	<0.5	<0.5	<0.5	<0.5	100	21 c 11 nc
2-Chloroethylvinyl ether	0.3	nd	nd	nd	nd	nd	nd	ns	ns	ns	ns	ns	ns	3540*	no value
Chloroform	nd	nd	6.7	1	trace	nd	nd	<0.1	ns	0.5	<0.5	<0.5	<0.5	700	8 c 61 nc
Ethylbenzene	nd	nd	39	nd	nd	nd	nd	<2.0	ns	<0.5	<0.5	<0.5	<0.5	5	1300 nc
Methylene chloride	nd	nd	3.8	1.1	nd	nd	nd	ns	ns	<0.5	<0.5	<0.5	<0.5	5	215 c 1600 nc
Tetrachloroethylene	nd	nd	0.2	nd	nd	nd	nd	<0.1	<0.1	<0.5	<0.5	<0.5	<0.5	5	55 c 250 nc
1,1,1-Trichloroethane	nd	ns	nd	nd	2.1	nd	nd	<1.0	ns	<0.5	<0.5	<0.5	<0.5	200	790 nc

Table 6. Production/drinking Water Well Monitoring Data (1983 -1995), Volatile Organic Compound Concentration (μg/L) for Well 1044, Kelly Air Force Base (continued)

Chemical	Organization Collecting and Analyzing Sample with Month and Year of Sample (μg/L)													Screening Values	
	Sampling as part of the SDWA		Sampling as part of the IRP program			Sampling as part of the SDWA									
	OEHL 11/83	Radian 1/86	OEHL 1/86	OEHL 3/86	OEHL 3/86 (split)	OEHL 4/86	OEHL 5/86	TDH 7/88	TDH 12/93	TDH 3/94	TDH 7/94	LCRA 8/95	LCRA 11/95	EPA MCL or LTHA (μg/L)	EPA RBCs (6 Years of Exposure at 1/100,000) (μg/L)
Trichloroethylene	nd	nd	2.2	nd	nd	nd	nd	<0.1	<0.1	<0.5	<0.5	<0.5	<0.5	5	80 c 35 nc

Notes:

* No human health based screening levels were available for 2-chloroethylvinyl ether. This value is the surface water screening values derived by U.S. EPA Region 4 Water Management Division. These values were obtained from Water Quality Criteria documents and represent the chronic ambient water quality criteria values for the protection of aquatic life.

Key: Source: Kelly AFB (no date).
c = cancer
nc = noncancer
EPA RBCs = EPA Region 6 Risk Based Concentrations based on 30 years of exposure 24 hours a day, 350 days per year, and exposure via ingestion and incidental inhalation.
LCRA = Lower Colorado River Authority

LTHA = Lifetime Health Advisory for drinking water
MCL = EPA's maximum contaminant level
nd = not detected
OEHL= Occupational Environmental Health Laboratory

Table 6. Production/drinking Water Well Monitoring Data (1983 -1995), Volatile Organic Compound Concentration (μg/L) for Well 1044, Kelly Air Force Base (continued)

μg/L = micrograms per liter
TDH = Texas Department of Health

Table 7. Selected history of Wells 313 and 314, Kelly Air Force Base

Date	Well	Event
11/83	313 and 314	Kelly Air Force Base (KAFB) sampled Wells 313 and 314 and analyzed them for VOCs for the first time. No contaminants were measured above detection limits.
4/85	313 and 314	KAFB sampled Wells 313 and 314 for selected compounds; no contaminants were measured above detection limits.
1/22/86	313 and 314	KAFB sampled Wells 313 and 314. Samples were analyzed by the Air Force's Occupational Environmental Health Laboratory and Radian Corporation, a contractor. Several compounds were detected, but not above MCLs.
3/11/86	313 and 314	KAFB sampled Wells 313 and 314. Samples were split and analyzed by the Air Force's Occupational Environmental Health Laboratory. Several compounds were detected, but not above MCLs.
4/16/86	313 and 314	KAFB conducted routine sampling in accordance with the EPA Safe Drinking Water Act (SDWA). Tetrachloroethylene (PCE) was detected in Well 313 at 0.12μg/L.
5/15/86	313 and 314	KAFB sampled Wells 313 and 314. No contaminants were detected above detection levels.
07/07/88	313 and 314	TDH conducted sampling. In the sample from Well 314, no contaminants were measured above detection limits. In the sample from Well 313, PCE was detected at 5.5 μg/L, which exceeds the MCL. During the month of July, this well contributes less than 30 percent of the total water distributed by the base water distribution system.
08/11/88	313 and 314	KAFB sampled the two wells. PCE was not measured above the detection limit (<0.1 μg/L).
09/23/88	313 and 314	TDH conducted confirmation sampling of the two wells, and no contaminants were measured above detection limits. No corrective action was required under SDWA.
01/31/89	313	KAFB took Well 313 out of service to repair the pump; use of the well was never resumed.

Table 7. Selected history of Wells 313 and 314, Kelly Air Force Base (continued)

Date	Well	Event
06/23/89	313	On 6/22/89, to investigate the sound of running water in the well casing, a TV study was conducted, revealing a 12" diameter horizontal pipe about 30 feet deep. The pipe ran into the well's casing at 31 feet below ground level. The pipe was formerly used to convey water under artesian pressure from the well to a distribution system located between Wells 313 and 314. During the 1970s, pumps were installed in the two wells, the distribution system was shut down, and associated pipes were reportedly capped. A sample of the water running from this pipe was collected; results revealed that it contained PCE at 52 μg/L. However, this concentration is not considered precise because of the way the instruments used were calibrated. Levels of other chlorinated solvents were not measured in the sample. Metal levels were below detection limits. No information about how long the pipe had been present is available.
06/26/89	313	KAFB had a three-foot plug placed in front of the horizontal pipe to prevent water in the pipe from entering the production well.
07/14/89	314	KAFB sampled Well 314 for parameters that include VOCs, and no contaminants were measured above detection limits.
07/17/89	313	An additional TV study showed a one-ft gap in the well at a depth of 590 feet.
09/01/89	313	A Kelly AFB memorandum to the file raised questions about the source of contamination in Well 313 and whether contamination might have been a problem elsewhere in the base's water supply system.
09/06/89	314	KAFB sampled Well 314 for metals and related parameters; no contaminants were detected at levels of concern.
10/12/89	314	KAFB sampled Well 314 for parameters that included VOCs, and no contaminants were measured above detection limits.
10/13/89	313	Fuel contamination reported in an IRP monitoring well near Well 313.
02/01/90	314	Samples collected from Well 314 did not contain detectable concentrations of any regulated chemicals, but certain chlorinated solvents were detected at low levels, below or slightly exceeding ATSDR's most conservative comparison values.
03/06/90	314	A horizontal pipe similar to the one discovered entering Well 313 was reported present in Well 314. Although no water was observed entering the well from the pipe, it is not known whether this may have occurred in the past.
04/11/90	314	Installation of a patch to prevent water in the horizontal pipe from entering this production well completed.
03/26/91	313	KAFB concluded that the water in the horizontal pipe was coming from the shallow alluvial aquifer.

Table 7. Selected history of Wells 313 and 314, Kelly Air Force Base (continued)

Date	Well	Event
06/16/91	313	Well 313 cemented and permanently sealed.
06/21/98	314	Well 314 permanently sealed.

Source: Gargiulo 1998b.

Key:

KAFB = Kelly Air Force Base
MCL = EPA's maximum contaminant level
SDWA = Safe Drinking Water Act
TDH = Texas Department of Health.

Table 8. Individual Well Production for 1983 and 1984 in 1000 gallons*

	Individual Well Production in 1983 / 1000 gallons							
	313	**141**	**314**	**1638**	**1556**	**1044**	**3010**	**1536**
January	3210	27108	42405	0	1272	9055	15639	0
February	1446	28836	38742	0	10776	6600	2952	0
March	692	31455	36969	0	23472	8183	4056	0
April	819	32395	32091	0	22560	12845	14340	0
May	2172	33939	35132	0	16464	12206	22269	0
June	28126	24408	22454	0	22704	11513	17316	0
July	32975	30159	15103	0	23520	12659	18681	0
August	30677	33696	24259	0	27024	13541	16731	0
September	34551	10470	27521	0	23376	12735	24258	0
October	38177	5130	29132	0	16824	13834	20358	0
November	28440	20898	17696	0	16272	4176	19656	0
December	29021	19431	18288	0	17634	264	19278	0
Annual total	**230306**	**297925**	**339792**	**0**	**221898**	**117611**	**195534**	**0**
Average per month	19192	24827	28316	0	18492	9801	16294	0
Average gallons per minute	437	565	645	0	421	223	371	0
Ratio 313/314	0.68							

Table 8. Individual Well Production for 1983 and 1984 in 1000 gallons (continued)*

	Individual Well Production in 1984 per 1000 gallons							
	313	**141**	**314**	**1638**	**1556**	**1044**	**3010**	**1536**
January	33741	20637	10911	0	16828	1574	7227	11104
February	29452	16838	10068	0	10549	5185	5432	11961
March	34412	27290	17658	0	8120	11570	5685	7478
April	33967	28133	25401	0	8515	13135	9459	8726
May	38015	34398	28465	0	8841	11014	11108	15792
June	38019	36805	32150	0	17003	11551	14908	5696
July	39808	37044	32992	0	11426	14797	33933	0
August	36057	36045	30060	0	13696	14951	18262	17016
September	37247	25723	17527	11760	6660	12482	11054	15875
October	37053	10071	19805	22419	7638	4639	1595	12734
November	33719	0	16343	16416	14072	8333	14615	2613
December	33125	0	25643	11090	11716	3378	8089	15913
Annual Total	**424615**	**272984**	**267023**	**61685**	**135064**	**112609**	**141367**	**124908**
Average per month	35385	22749	22252	5140	11255	9384	11781	10409
Average gallons per minute	806	518	507	117	256	214	268	237
Ratio 313/314	1.59							

*ATSDR obtained and reviewed the production well data for years 1983 through 1988. 1983 was the year Kelly AFB began sampling the wells and 1988 is the year that Well 313 was discontinued. The production volumes change from year to year so the calculated concentrations would also change depending on the relative production from Wells 313 and 314. For the calculated concentrations, ATSDR used the values that produced the highest concentrations to be more protective of public health in this evaluation. In these cases, 1983 produced the highest concentrations in the calculations in Appendix C-1 and 1984 produced the highest concentrations in the calculation in Appendix C-2.

Table 9. Pathway Table; Summary of Exposure to Water from Wells 313 and 314 Pathway Elements.

Contaminants	Exposure Pathways Elements					Dates and Duration of Exposure	Comments
	Source	Environmental Media	Point of Exposure	Route of Exposure	Exposed Population		
1,2-dichloroethane, benzene, chloroform, ethylbenzene, methylene chloride, 1,1,1,2-tetrachloroethane, tetrachloroethylene, 1,1,2-trichloroethane, and trichloroethylene	Shallow groundwater	Water	Water taps, faucets, and spigots throughout the base.	Ingestion, inhalation, dermal contact	A subgroup of civilian and military personnel and families on-base. Population estimates from 1983 to 1990 vary from 23,000 to 29,000 per year. Potential exposed population is estimated at 14,000.	Past, maximum estimates are about six years, from late 1983 to early 1990.	No Apparent Public Health Hazard

Figure 2. Well Inventory in Bexar County, Texas

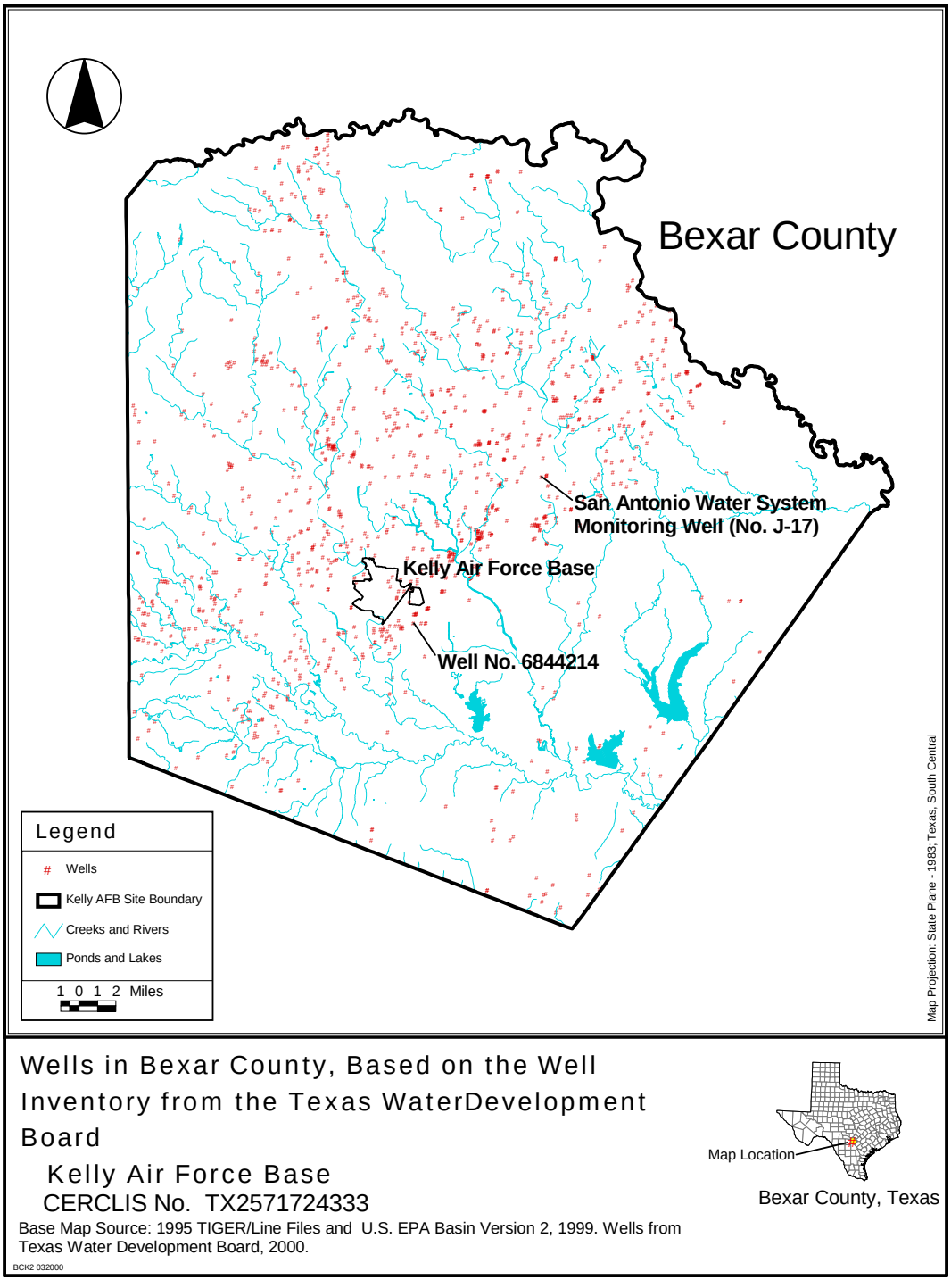


Figure 3. Drinking water/production wells 313 and 314, IRP monitoring wells, and shallow groundwater information.

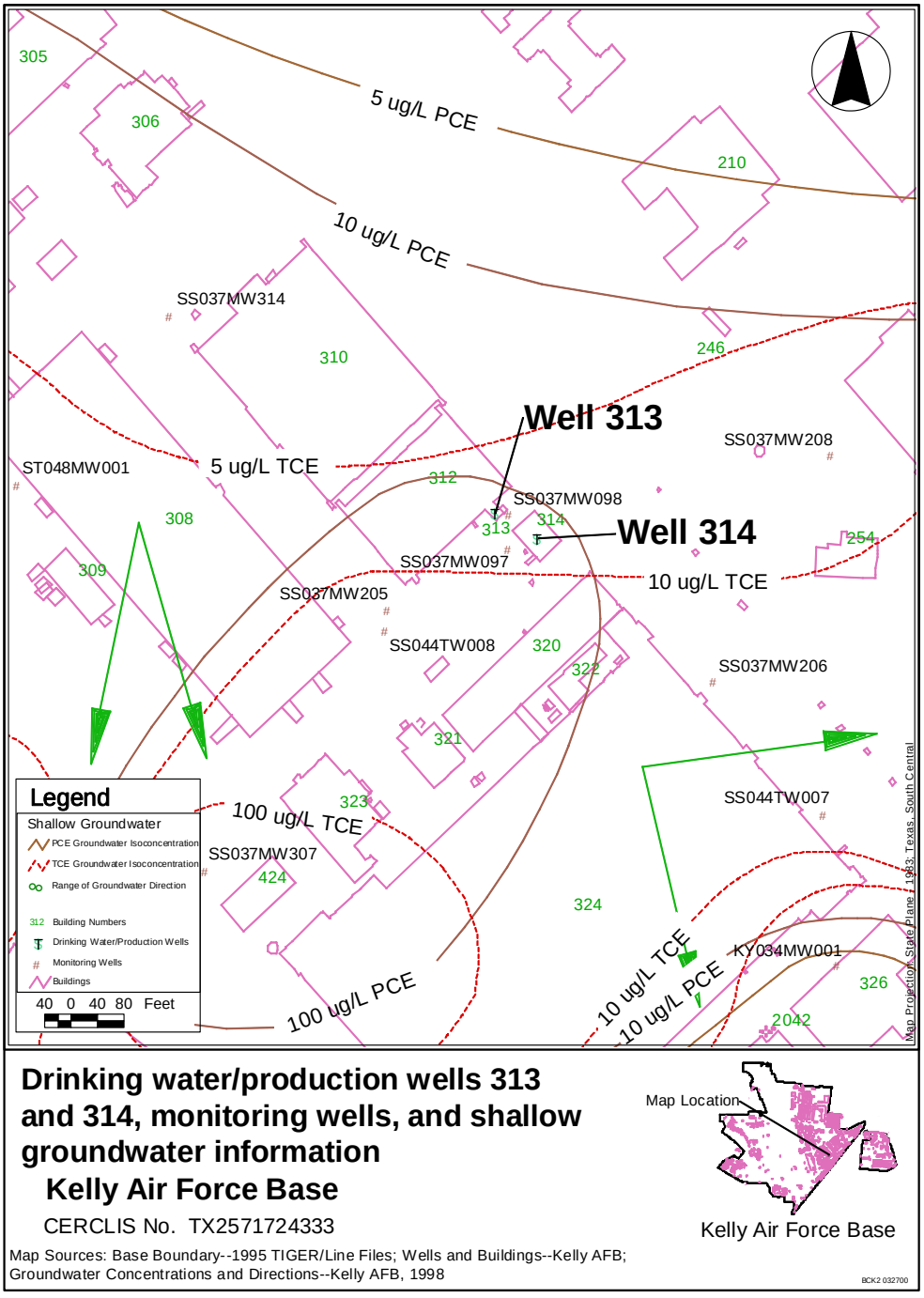
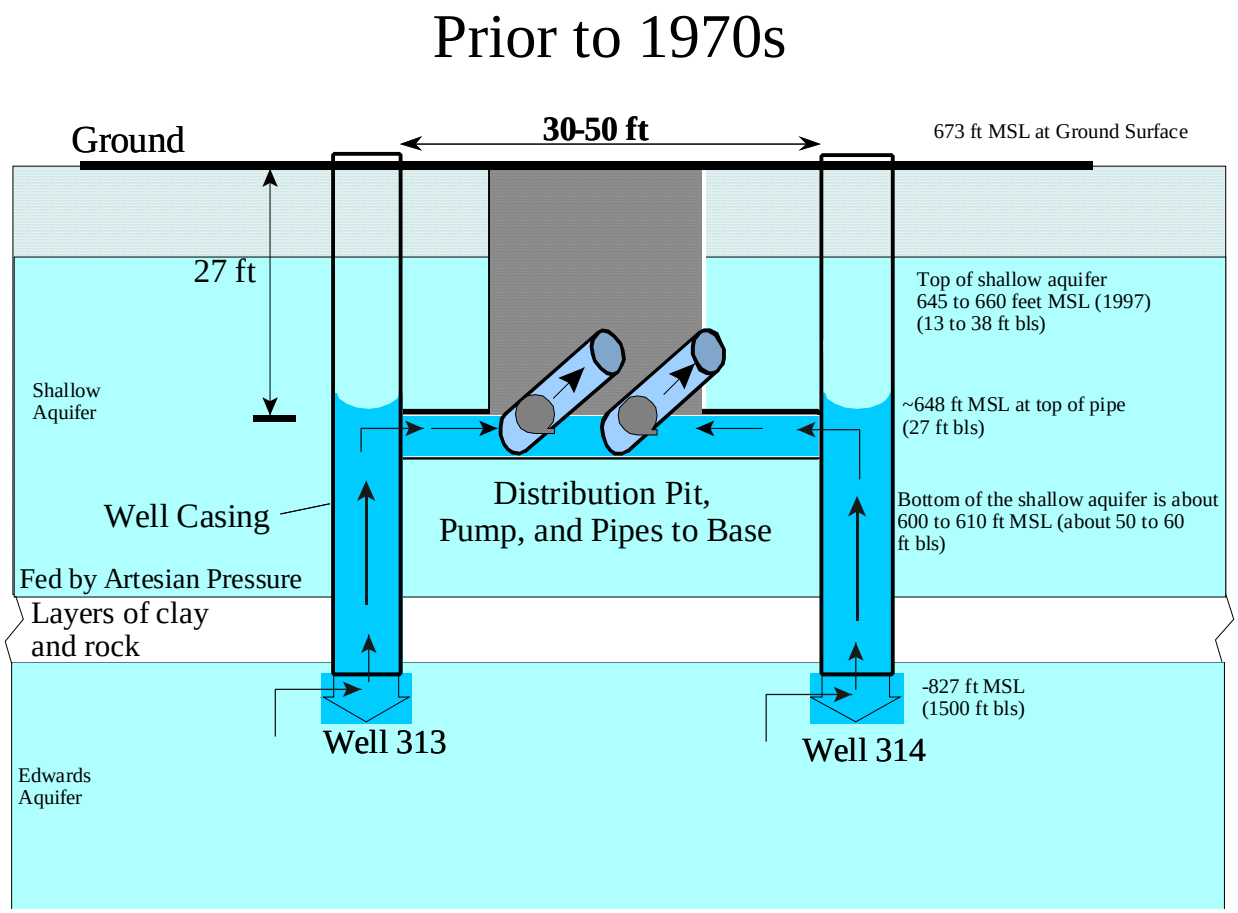


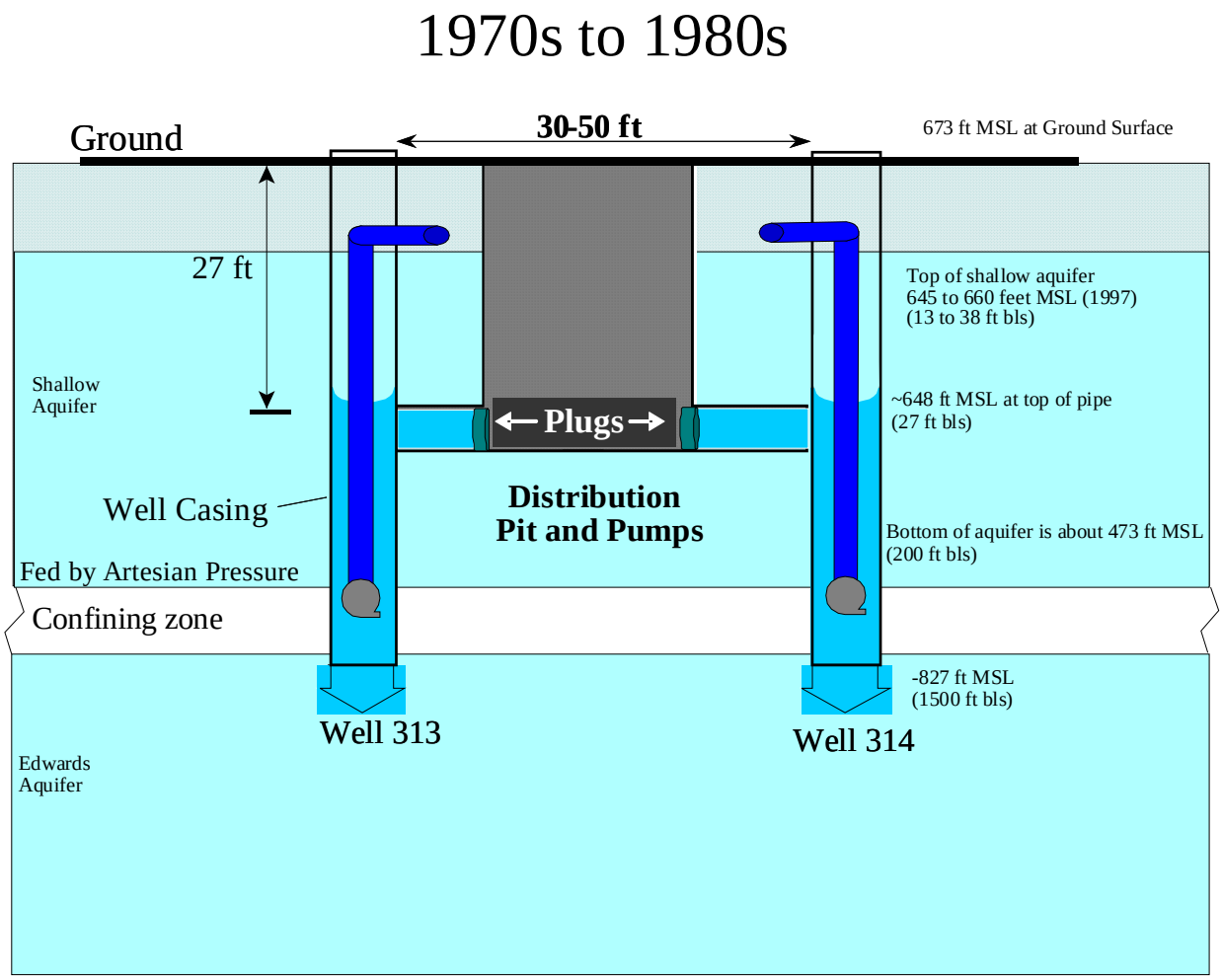
Figure 4. Simplified schematic of Wells 313 and 314 with horizontal pipe when pumps were located out of the wells.



Based on a drawing from Gargiulo (1998)

Key:
bgs = below ground surface
MSL = mean sea level

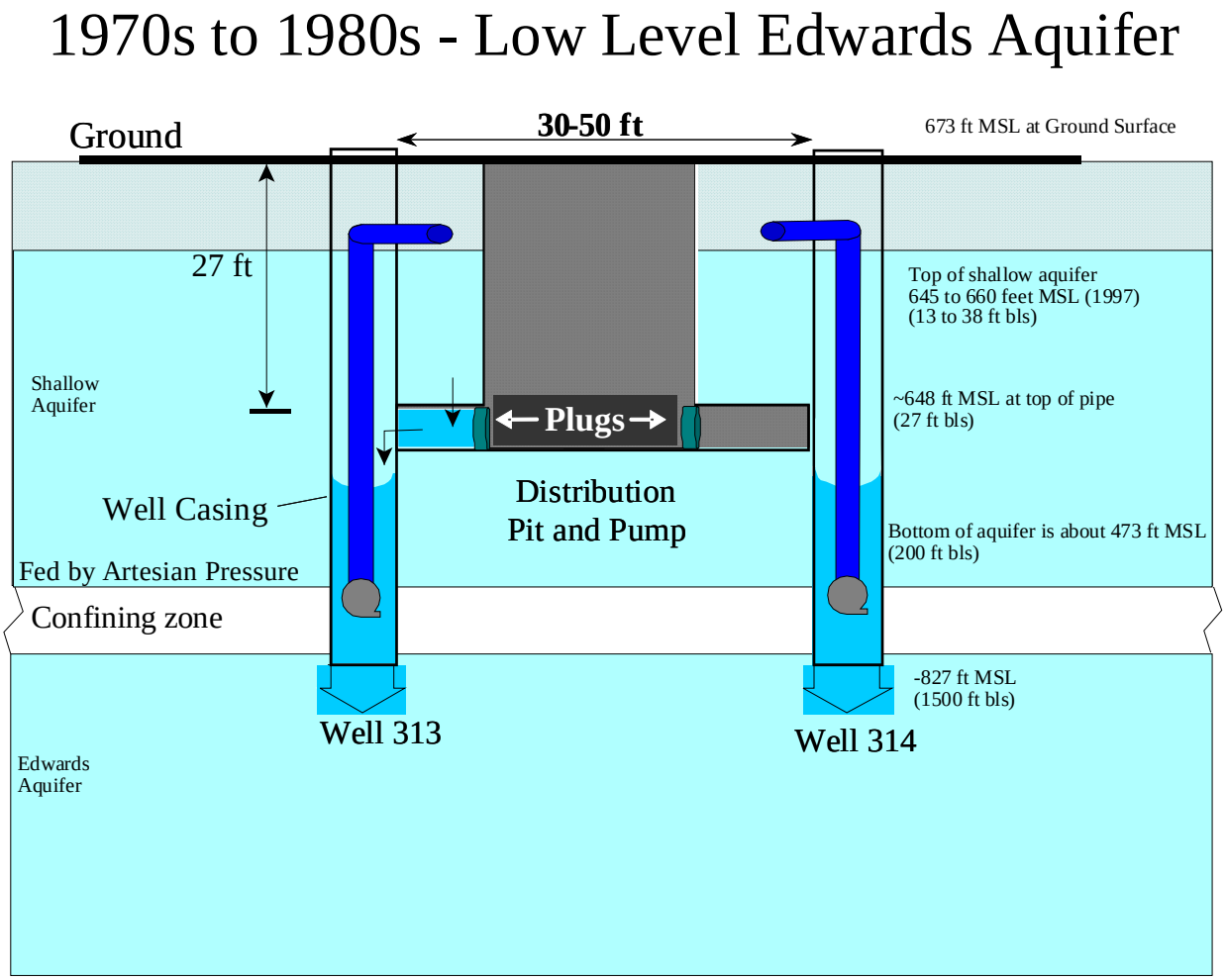
Figure 5. Simplified schematic of Wells 313 and 314 with horizontal pipe after pumps were moved to the wells with no leak in the horizontal pipe.



Based on a drawing from Gargiulo (1998)

Key:
bgs = below ground surface
MSL = mean sea level

Figure 6. Simplified schematic of Wells 313 and 314 with a leak in the horizontal pipe and relative low water level in the Edwards Aquifer.*



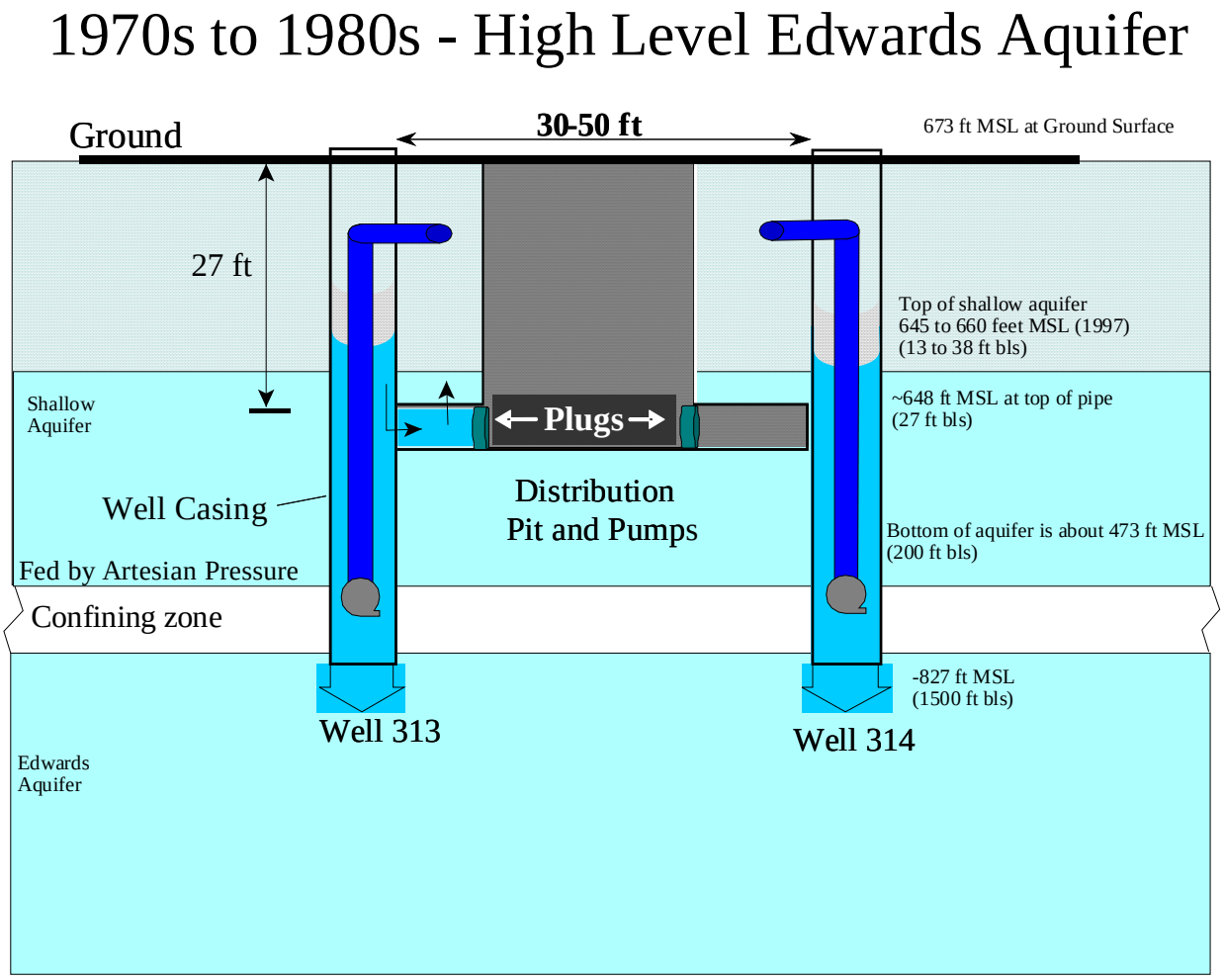
Based on a drawing from Gargiulo (1998).

Notes:

* As a result of the greater hydrostatic pressure in the shallow aquifer compared to the Edwards Aquifer, water will flow from the shallow aquifer through the leak into the horizontal pipe and well casing and mix with water up welling from the Edwards Aquifer.

Key:
bgs = below ground surface
MSL = mean sea level

Figure 7. Simplified schematic of Wells 313 and 314 with a relative high water level in the Edwards Aquifer.*

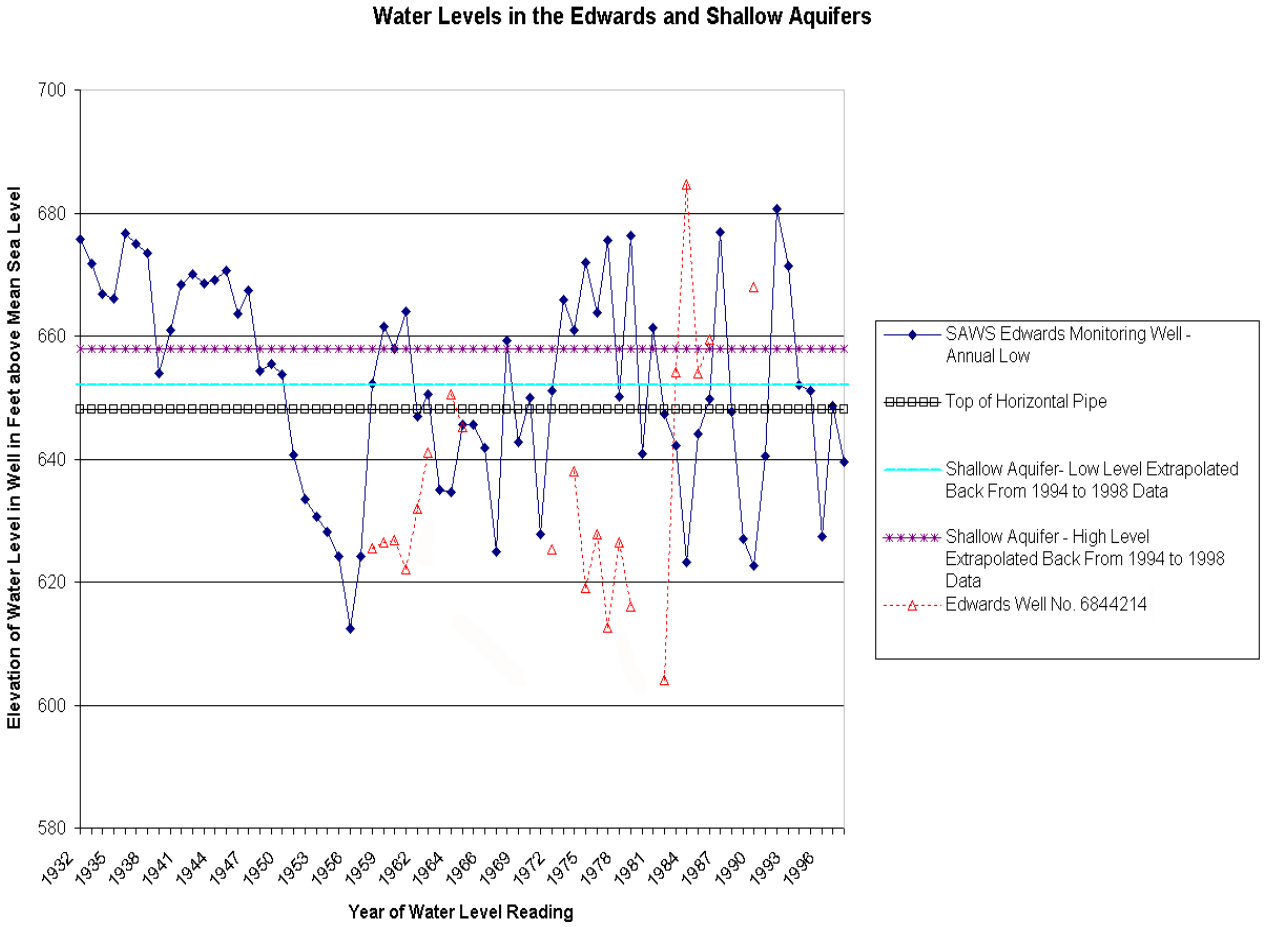


Based on a drawing from Gargiulo (1998).

Notes:
As a result of the greater hydrostatic pressure in the Edwards Aquifer compared to the shallow aquifer, water will flow from the Edwards Aquifer through the well casing into the horizontal pipe, through the leak, and into the shallow aquifer.

Key:
bgs = below ground surface
MSL = mean sea level

Figure 8. Water Level Readings from the San Antonio Water System Edwards Aquifer Monitoring Well (J17) and Private Well Number 6844214 in Relation to the Shallow Aquifer Water Levels and the Depth of the Horizontal Pipe.



Appendix A. Screening Values

Screening values were obtained from U.S. EPA Region 6* and modified to site-specific exposure conditions and risk levels. Only cancer screening values were modified. Region 6 cancer screening values are based on 30 years exposure as an adult and a target risk of 1/1,000,000 with exposure via ingestion and incidental inhalation. ATSDR modified the cancer screening values to six years and a target risk of 1/100,000 by multiplying the screening values by 50 (5 for the conversion from 30 to six years; 10 for the conversion from 1/1,000,000 to 1/100,000).

The six years is based on the 6 years of exposure discussed in the Data Evaluation and Interpretation Section of this consultation. Because Region 6 cancer screening values assume six years as a child and 24 years as an adult, the conversion includes child and adult exposures**.** The conversion from 1/1,000,000 to 1/100,000 is based on the following ATSDR cancer risk categories, in which 1/100,000 is considered no apparent increased risk of cancer:

Category Definitions† of Cancer Risk

Category	Fraction	Decimal	Exponential
No Increased Risk	<1/100,000	<0.00001	<1E-05
No Apparent Increased Risk	1/100,000	0.00001	1E–05
Low Increased Risk	1/10,000	0.0001	1E–04
Moderate Increased Risk	1/1,000	0.001	1E–03
High Increased Risk	1/100	0.01	1E–02
Very High Increased Risk	>1/100	>0.01	>1E–02

Notes:
*Available at http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm

†ATSDR's category definitions define categories of estimated risk to convey the degree of hazard from the defined exposure relative to other exposures.

Appendix B. Well 1044

Well 1044 exceeded MCLs once for 1,2-dichloroethane, 1,4-dichlorobenzene, and chlorobenzene in January 1986. A second sample collected in January 1986 and subsequent samples collected in March and April of 1986 from this well did not exceed the MCL. In five subsequent samples from the well, collected July 1988 through November 1995, volatile organic compounds were not detected (See Table 6).

Kelly AFB investigated the inconsistency of the sampling results from Well 1044 and other wells sampled in 1986. They concluded that the following errors occurred in the sampling protocol:

- The same sampling-collection equipment was used for IRP monitoring well samples and drinking water well samples.
- Cleaning of sample-collection equipment between sampling of IRP monitoring wells and drinking water well samples was inadequate.
- Samples collected from the IRP monitoring wells were switched with drinking water samples (Gargiulo 1998).

Because the MCLs were exceeded in only one sampling—and because this sampling may have been flawed—ATSDR considered the January 1986 samples not to be representative of the water in the well.

Appendix C. Calculations

Appendix C-1. Calculation of concentration in water combined from Wells 313 and 314 using 1984 production data because it provides the highest concentrations for this calculation.

Chloroform

$$\frac{806 \text{ gpm } (12\ \mu\text{g/L}) + 507 \text{ gpm } (1^*\ \mu\text{g/L})}{806 \text{ gpm} + 507 \text{ gpm}} = 7.8\ \mu\text{g/L}$$

1,2-Dichloroethane

$$\frac{806 \text{ gpm } (43\ \mu\text{g/L}) + 507 \text{ gpm } (1^*\ \mu\text{g/L})}{806 \text{ gpm} + 507 \text{ gpm}} = 26.8\ \mu\text{g/L}$$

Tetrachloroethylene

$$\frac{806 \text{ gpm } (5.5\ \mu\text{g/L}) + 507 \text{ gpm } (1^*\ \mu\text{g/L})}{806 \text{ gpm} + 507 \text{ gpm}} = 3.8\ \mu\text{g/L}$$

* When not reported, 1 μg/L is assumed to be the detection limit.

Appendix C-2. Calculation of concentration of well water with shallow aquifer water at 100 μg/L and 10 μg/L flowing into the well at 10 gpm and 50 gpm, using 1983 production data because it provides the highest concentrations for this calculation.

- Water from Well 313 combining with water from the shallow aquifer at 10 gpm

  $$\frac{(1\ \mu g/L \times (437\ gpm - 10\ gpm)) + (100\ \mu g/L \times 10\ gpm)}{437\ gpm} = 3.26\ \mu g/L \text{ tetrachloroethylene}$$

  $$\frac{(1\ \mu g/L \times (437\ gpm - 10\ gpm)) + (10\ \mu g/L \times 10\ gpm)}{437\ gpm} = 1.21\ \mu g/L \text{ trichloroethylene}$$

- Combining with Well 314

  $$\frac{437\ gpm\ (3.26\ \mu g/L) + 645\ gpm\ (1\ \mu g/L)}{437\ gpm + 645\ gpm} = 1.92\ \mu g/L \text{ tetrachloroethylene}$$

  $$\frac{437\ gpm\ (1.21\ \mu g/L) + 645\ gpm\ (1\ \mu g/L)}{437\ gpm + 645\ gpm} = 1.19\ \mu g/L \text{ trichloroethylene}$$

- Water from Well 313 combining with water from the shallow aquifer at 50 gpm

  $$\frac{(1\ \mu g/L^{*}\ (437\ gpm - 50\ gpm)) + (100\ \mu g/L\ *\ 50\ gpm)}{437\ gpm} = 12.3\ \mu g/L$$

  $$\frac{(1\ \mu g/L\ *\ (437\ gpm - 50\ gpm)) + (10\ \mu g/L\ *\ 50\ gpm)}{437\ gpm} = 2.03\ \mu g/L$$

- Combining with Well 314

  $$\frac{437\ gpm\ (12.3\ \mu g/L) + 645\ gpm\ (1\ \mu g/L)}{437\ gpm + 645\ gpm} = 5.57\ \mu g/L \text{ tetrachloroethylene}$$

  $$\frac{437\ gpm\ (2.03\ \mu g/L) + 645\ gpm\ (1\ \mu g/L)}{437\ gpm + 645\ gpm} = 1.42\ \mu g/L \text{ trichloroethylene}$$

Appendix D. Information about the Edwards Aquifer.

To understand the Edwards Aquifer, one must understand how the aquifer was formed and how water is transmitted through it. The formation of the Edwards Aquifer began around 100 million years ago when the ocean periodically covered southeastern Texas. When southeastern Texas was covered by the ocean, limestone forming sediments from the water settled to the bottom and formed the Edwards Aquifer consisting of limestone. During times when the ocean receded, erosion created cavities and conduits making the Edwards Aquifer capable of holding and transmitting water. At some point, the sediments settling on the ocean floor changed from limestone-forming materials to clays and these clays covered the limestone. The clays were relatively impermeable to water. These clays formed a confining unit which prevented water from seeping into the Edwards Aquifer from above.

Beginning about 70 million years ago, mountains west of San Antonio began forming. Millions of tons of sediments, carried by the wind and water settled on Texas. The formation of these sediments resulted in a thicker layer of sediment towards the coast. The tremendous weight of the sediments caused a series of parallel faults in the Edwards Aquifer. The limestone layers that had originally been flat became tilted, exposing a section of the Edwards Aquifer at the surface in an area known as the Balcones Fault Zone. This zone, comprised of 1,500 square miles north and west of San Antonio, contributes large amounts of water to the aquifer. Once the Edwards Aquifer runs beneath the ground, the soils above the aquifer prevent surface water from migrating into it under natural conditions. Under Kelly AFB, the aquifer lies 1,500 feet below ground surface[1]

[1] This information was obtained from http://www.edwardsaquifer.net/geology.html.

Appendix E. Air Force Comments on ATSDR's Health Consultation on Past Exposure to Drinking Water From On-Base Wells 313 and 314, Kelly AFB - 1 June 2001 (Draft) and ATSDR's Responses

	Location	Air Force Comment	Response
1	Page 3	"Groundwater Contamination in the Shallow Aquifer"—This section should briefly state why the "shallow aquifer is the most likely source of contamination to Well 313."	The text has been updated to explain that the shallow aquifer is the most likely source of contamination in Well 313 because a leak was discovered in the well casing. The breach allowed the shallow groundwater to leak into the Edwards Aquifer Well 313
2	Page 3	"Groundwater Contamination in the Shallow Aquifer" — Second paragraph, last sentence - The analysis levels are confusing. Please reference Table 3 to help clarify.	The reference to Table 3 has been added.
3	Page 8	Paragraph 1—Please explain how the short duration time for exposure was deduced. Paragraph 2—Which Region 6, EPA or ATSDR, and if it is EPA, then why the different screening levels by the same agency?	Paragraph 1. The short duration for exposure is defined as six years. The actual length of exposure is not know but was assumed to be six years on the basis of available data. A reference has been added to refer readers to Page 6. Paragraph 2. Screening values are not absolute. They differ from author to author on the basis of the data available and according to their scientific judgment. Screening values can also differ within the same agency. ATSDR presented EPA Region 6, EPA Region 9, and ATSDR values as a comparison of the ranges that have been published and used by health and risk assessors. Paragraph 2 discusses the noncancer screening value for 1,2-dichloroethane. The Region 6 screening value that was withdrawn (for a reason unknown to ATSDR) was based on a reference dose of 0.0029 mg/kg/day. ATSDR's screening value was based on a reference dose 100 times higher, 0.2 mg/kg/day. Region 9's screening value is based on a reference dose that is about halfway between ATSDR's and Region 6's at 0.03 mg/kg/day. As one can see, a wide variety in reference doses exists. Regardless, the maximum concentrations detected in Well 313 water (which was distributed at a lower concentration because of mixing with Well 314 water) would have been below levels of concern no matter which reference dose was used. ATSDR has added a footnote to the text to clarify.
4	Page 9	Paragraph 3 and "Conclusion"—Interchanging screening levels and MCLs is confusing. Please define screening	MCLs (maximum contaminant levels) are the highest levels of a contaminant allowed in drinking water. MCLs are based on health risks and available

	Location	Air Force Comment	Response
		levels and the MCLs and their differences.	technology for treating water. MCLs are based on a lifetime of exposure. As a result, MCLs are a good benchmark for determining if a health risk exists. In the evaluation of exposure to contaminated drinking water at Kelly AFB, ATSDR concluded that a 6-year exposure period was more likely than a lifetime exposure. Therefore, ATSDR created a screening value based on this shorter exposure period. In the text, concentrations are compared to MCLs and screening values for comparison and evaluation. ATSDR has added a footnote to the text to clarify.
5	Page 9	"Conclusion" – This section states that if the chemical was present, the reported concentration was at a relatively low concentration for a short period of time. Provide an example of the times and concentrations and provide the source of this data.	Low concentrations mean below screening values and short period of time means 6 years or less. ATSDR clarified this in the text.
6	Page 29, Figure 3	Suggest enlarging and/or bolding the text designations for Wells 313 and 314 within the figure so that they are easier to locate.	ATSDR has enlarged and bolded the text designations for Wells 313 and 314 for readability.

Appendix F

Response to Comments from External Peer Review of Past Exposure to Drinking Water from On-Base Wells 313 and 314, Kelly Air Force Base, San Antonio, Texas.

1. Does the public health consultation adequately describe the nature and extent of contamination?

A. Reviewer Number 1

Comment:
The description of local hydrological phenomenon, history of wells 313 and 314, and Kelly AFB water distribution system is thorough. The pictorials (figures) were very helpful. The information on water sampling and laboratory test results obtained over time for a variety of wells is helpful.

Response:
No response is needed.

B. Reviewer Number 2

Comment:
The nature and extent of water contamination has been adequately described. But more importantly, the authors have made an excellent effort to explain how the contamination of wells 313 and 314 came about. Through the use of diagrams, it is easy to see how the leak in the cross pipe resulted in contamination.

The authors did a good job of explaining how they computed the likely levels of contamination. This is not a particularly easy or obvious concept to explain, but the authors did a credible job.

The chemicals that people were exposed to in the past were listed and probable concentrations are given. It was also obvious that the authors used highly conservative approaches in order to produce a worst case scenario which should afford levels of comfort for people who may have consumed contaminated water in the past.

Response:
No response is needed.

C. Reviewer Number 3

Comment:
The nature of the contamination is clearly described. Shallow groundwater became contaminated with organics from surface activities, and plumbing failures in a connector pipe between two wells led to the mixing of this shallow groundwater with water in the much deeper Edwards aquifer. The consultation makes a clear point that the exact date when this contamination first took place is unknown, therefore a reasonable, conservative assumption was made that the contamination commenced at the earliest sampling date in 1983. No significant (above indicator values) contamination was observed until 1986, however.

The extent of the contamination is also clearly and adequately described. It is shown graphically in Figure 3 for the two contaminated deep wells (Edwards aquifer) and the surrounding shallow groundwater monitoring wells. The nature of fluctuation in groundwater levels and the way it would have influenced flow between the shallow and deep aquifers is adequately discussed, although it is clearly not possible to say quantitatively how much water flowed between the two sources.

Response:
No response is needed.

2. Does the public health consultation adequately describe the existence of potential pathways of human exposure?

A. Reviewer Number 1
Comment:
No. Little to no information is given regarding potential pathways of human exposure. Additionally, the official process is not described. For example, water consumption at work and/or at home, bathing and showering at home and at work, child care centers on base, industrial use of water, etc.

Response:
Page 3 includes the following information:

> The drinking water supply wells feed into a closed distribution system consisting of tanks, pumps, and pipes. The water is used exclusively for the base, both military and civilian personnel, and services on-base housing, industrial processes, operations, and office buildings. [. . .] The water was used for drinking, bathing, and cleaning in residential and industrial areas of the base. Exposure would have been through oral intake, inhalation if the contaminants volatilize during use, and dermal contact.

This document further states that the drinking water pumped from the wells underwent disinfection, fluoridation, and pH adjustment at the wellhead before being placed into the distribution system. There were also five storage tanks. Because multiple wells and tanks feed the drinking water system, the water in any one area could have been supplied by several wells from different parts of the base. It is unknown how much of the base was serviced by Wells 313 and 314. It is very likely that the size of the area changed often as pumping rates and pressures throughout the system changed minute-by-minute. Because of the on-base housing, ATSDR's evaluation included children and adults.

ATSDR has added additional information to the Health Consultation with this exposure pathway information.

B. Reviewer Number 2
Comment:
The only pathway considered was consumption of water. I feel the description was adequate.

Response:
No response is needed.

C. Reviewer Number 3
Comment:
The drinking water pathway is adequately examined, but there is no mention of potential exposure from the inhalation (during bathing) pathway or direct skin contact (during bathing) pathways. No other potential pathways exist. Based on the very low levels of contamination seen, and the infrequency with which they were seen, these pathways are probably negligible.

Response:
Page 3 includes a statement that exposure to the chemicals in the water would have been through oral intake, inhalation if the contaminants volatilize during use, and dermal contact. The text was revised to clarify that the EPA Region 6 screening values included exposure via ingestion and incidental inhalation. Dermal exposures were considered but not included because the risk from dermal absorption were 10 times or more below the risk from ingestion and inhalation and hence, not significant.

3. Are all relevant environmental and toxicological data (i.e., hazard identification, exposure assessment) being appropriately used?

A. Reviewer Number 1
Comment:
Questionable. There are numerous "judgemental" calls throughout this document. The "judgmental" calls also lack consistency. I would suggest that the data be presented and analyzed in a consistent manner.

Results are results. I understand the discussion of the improbability of some of the lab results- but they were the lab results! Present calculations and display tables with the worst case, most probably case, and most optimistic case.

Discuss (present rationale) for which case ATSDR considers most appropriate in a discussion section, not the results section! I, for one, would argue against the assumption used to calculate

results that exposure began only when testing was mandated by the Safe Drinking Water Act! That's OK for a point of discussion, but not for a worst-case scenario calculation in the results section.

Response:
The exact accounting of exposure will never be known because water samples for volatile organic compounds (VOCs) were never collected at the point of use. The accounting would have included the list of chemicals in the water, their concentrations, information about the people using the water, the use of the water, the amount of water used, and the date and time the water was used. This data were never collected and cannot be recreated accurately. The only chemical data available to ATSDR were the analysis of water from Well 313 and 314 (collected beginning in 1983), the analysis of water in the shallow aquifer collected as part of the Installation and Restoration Program beginning in 1983, and the analysis of water collected from the horizontal pipe when water was found to be running into Well 313 in 1989. Other information used in the analysis included Well 313 and 314 pumping rates and aquifer levels of the shallow aquifer and Edwards Aquifer.

The first issue of exposure analysis was to determine when Wells 313 and 314 became contaminated. The first samples were collected in November 1983. VOCs were not detected in water from Well 313, while 1,4-dichlorobenzene was detected in Well 314 at 75 μg/L, which is also the Safe Drinking Water Act Maximum Contaminant Level (MCL) for that chemical. 1,4-dichlorobenzene was not detected again in Well 314 through 1998 (the last date ATSDR evaluated), a period of 16 years. Wells 313 and 314 were then sampled five times in 1986. Various VOCs were detected (Tables 4 and 5) and the data are discussed in the text of the report.

Tetrachloroethylene, the chemical detected in the water leaking from the horizontal pipe into Well 313 in 1989, was never detected in Well 314. It was first detected in Well 313 in 1986 (one previous analysis in 1983 did not detect it).

Based on these facts, ATSDR assumed that exposure began in 1983 when only one chemical, 1,4-dichlorobenzene, was detected. ATSDR also considered the relative water levels of the shallow and Edwards Aquifer in determining potential chemical contamination in Wells 313 and 314 but there are considerable uncertainties in the data (this approach is addressed in more detail in comment number 5). Therefore, selecting any date prior to testing would have been purely speculative and thus unscientific.

In 1986, Kelly AFB sampled Wells 313 and 314 five times, with one sample analyzed twice because VOCs were detected. Kelly AFB concluded that the some of the data was erroneous because of sampling errors. ATSDR considered the data as if they were not erroneous in its evaluation resulting in a more conservative exposure scenario.

The second issue of exposure was to determine the chemicals and concentrations to which people were exposed. Because exact information was not available, ATSDR evaluated the situation using two different methods. Each method required different "judgements" because all the needed information was not measured in 1986. The first method was to take the maximum values of the VOCs detected above the MCLs in the wells and adjust for the mixing of water from Wells 313 and 314 that occurred prior to distribution (Appendix C). The second method was more conservative. It calculated the water concentration in Well 313 (water did not leak into Well 314) on the basis of the concentrations of contaminants in the shallow aquifer and the amount of water that could have been leaking into the well from the shallow aquifer.

ATSDR recognizes that numerous "judgment calls" were made, and these are identified. These calls were necessary because of data that were not collected in the past. These "calls" were not consistent because ATSDR used different methods to estimate what the exposure concentrations may have been.

For clarity, ATSDR has summarized the results of the different methods used to calculate past concentrations (page 10). ATSDR has also clarified the text that refers to the 1,2-dichloroethane concentrations and durations of exposure (page 8) and explained the reason for not using relative water levels (page 5).

B. Reviewer Number 2
Comment: Yes

Response:
No response is needed.
C. Reviewer Number 3
Comment:
The hazard, in the form of chemical identification, exposure scenarios, exposure timelines and exposure points, are clearly and appropriately discussed. There do not seem to be any omissions. It does seem appropriate to conclude that 1,2-dichloroethane levels of 43 μg/L on a single sampling date are not representative, but even if it did occur it is reasonable to assume the exposure duration was short.

Toxicological endpoints include the various screening values such as MCLS, cancer screening values and reference doses from EPA region 9 and ATSDR. Corrected for short exposure, the l,2-dichloroethane levels are just below the cancer screening endpoint. Additionally, ATSDR's non-cancer reference doses are orders of magnitude higher (and therefore more protective of public health) than EPA values, so there are no issues of non-cancer toxicity interpretation based on "borderline" exposure cases or assumptions about exposure duration.

Based on the discussion above, all relevant environmental and toxicological data (ie., hazard identification, exposure assessment) appear to be appropriately used in this consultation.

Response:
No response is needed.

4. Does the public health consultation accurately and clearly communicate the health threat posed by the site?

A. Reviewer Number 1
Comment:
No. The conclusions depend too much on acceptance of too many 'a priori' arguments buried in the text of the report.

Response:
ATSDR concurs that there are many such arguments and assumptions in the report, but they are presented as methods to derive exposure concentrations. Without the assumptions and rationale, no conclusions could be drawn.

B. Reviewer Number 2
Comment:
The authors concluded that past exposures from the two wells were not likely to result in adverse health effects. Given the chemicals and probable concentrations involved, I am in total agreement with the authors.

Response:
No response is needed.

C. Reviewer Number 3
Comment:
ATSDR clearly and appropriately categorized health threats from the drinking water pathway as "no apparent public health hazard." This was adequate substantiated with the presentation of data and the discussion. Other health threats not discussed (inhalation and dermal exposure during bathing) were not considered or communicated, although these were probably negligible.

Response:
Page 3 includes a statement that exposure to the chemicals in the water would have been through oral intake, inhalation if the contaminants volatilize during use, and dermal contact. The text was revised to clarify that the EPA Region 6 screening values included exposure via ingestion and incidental inhalation. Dermal exposures were considered but not included because the risk from dermal absorption were 10 times or more below the risk from ingestion and inhalation and hence, not significant.

5. Are the conclusions and recommendations appropriate in view of the site's condition as described in the public health consultation?

A. Reviewer Number 1

Comment:

No. The report as written will not be accepted at face value. Those of us who "live and work" in the Alamo City will find it incongruous that no association regarding contamination of the Kelly AFB wells with the level of the Edwards Aquifer can be calculated for this time period. The ATSDR report concludes that no correlation can be made between potential "pumping" into the shallow aquifer from pressure in the Edwards Underground Aquifer versus reverse contamination from the contaminated shallow aquifer underlying Kelly AFB versus. This may be a technically correct observation, but, regional and local legal and regulatory actions aimed at industry, commercial establishments, and residences are implemented seasonally every year depending on the "level" of the aquifer reported on the 'Nightly News". I recommend reconsideration of this decision and presentation of some type of data regarding the number of at risk days that might add to your calculations of a worst-case scenario.

Response:

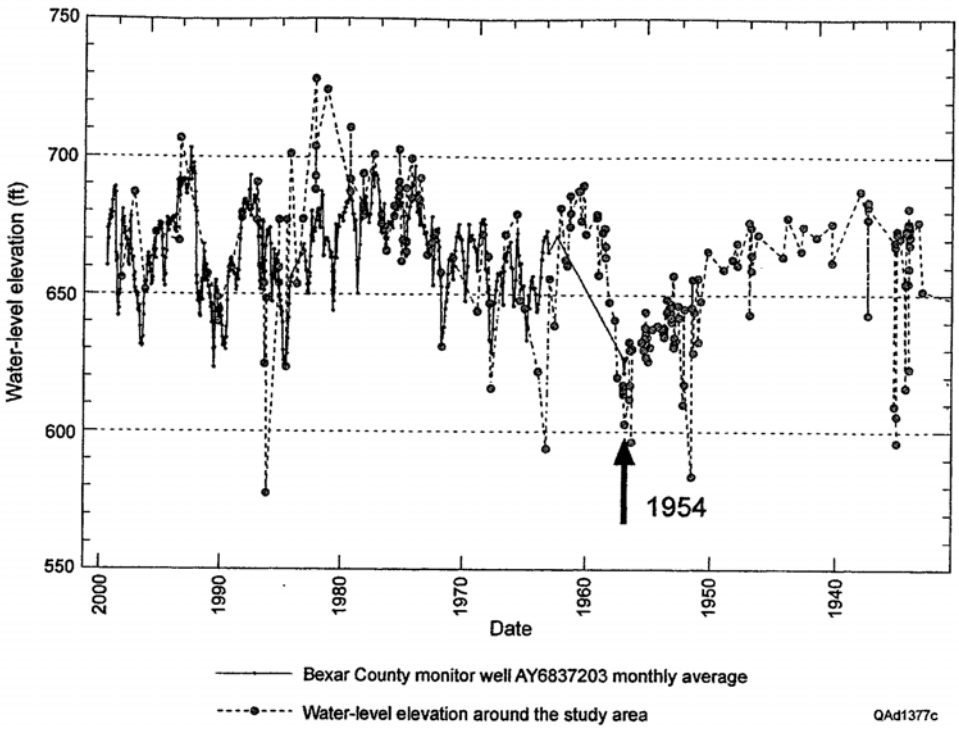
ATSDR understands that the legal and regulatory actions that depend on the "level" of the aquifer are based on water availability/use and managing supply and demand in an effective, efficient, and equitable way. Other actions unrelated to the "level" are for protection of the aquifer's water quality (John Cardit, Edwards Aquifer Authority, June 23, 2003). As the reviewer states, the level of the aquifer is closely monitored. However, ATSDR found that the level is not monitored at Kelly Air Force Base. To determine the potential for the shallow aquifer to flow into the Edwards Aquifer well, ATSDR reviewed the water levels in the Edwards and shallow aquifer.

ATSDR evaluated the possibility of interpolating on-base water levels of the Edwards Aquifer from off-base wells (Figure 8 in this report). ATSDR concluded that such interpolation was too uncertain because the water level in one Edwards Aquifer well near Kelly AFB (No. AY6844214) did not track with the San Antonio Water System well J-17 (AY6837203). This conclusion contradicts the generally accepted concept that the potentiometric surface (unconfined water levels) in the Edwards Aquifer are generally even while gently sloping down from north/northwest to southeast.[1,2,3] However, the figure on the following page, from Hovorka

[1] Bush, P.W., Ardis, A.F., and Wynn, K.H., 1993, Historical potentiometric surface of the Edwards-Trinity aquifer system and contiguous hydraulically connected units, west-central Texas: U.S. Geological Survey Water-Resources Investigations Report 92-4055, various scales, 3 sheets.

[2] John Cardit, Edwards Aquifer Authority, June 23, 2003 (personal communication)

et al[4], concurs with Figure 8 in this report, which shows that water levels do not necessarily track consistently across the aquifer.



Water-level elevation in the study area (Texas Water Development Board, 2002) plotted versus Julian day. For comparison, the monthly water-level elevations in the Bexar County monitor well (AY6837203) are plotted on the same scale. The 1954 synoptic survey is shown at the arrow.

[3] Scott Courtney, Booz, Allen, Hamilton, July 8, 2003 (personal communication)

[4]Hovorka, S.D., Paine, J.G., Reedy, R.C., July 2002. Final Report–Evaluation of the potential for cross contamination of the Edwards Aquifer from dissolved contaminants in the shallow groundwater zone in the vicinity of Kelly AFB via faults and wells.

As the figure above illustrates, the water level elevation of the Edwards Aquifer around the study area (dashed line) in the mid- to late 1980s does not track with well AY6837203 (J-17, solid line).

On the basis of our own evaluation of the Edwards Aquifer water level and the data illustrated in the figure above, ATSDR could not use the water level from J-17 or other wells to determine the Edwards Aquifer water level at Wells 313 and 314. The reasons for these differing water levels can include the screen location within the aquifer and recharge conditions and pumping withdrawals at the time of the elevation readings.

ATSDR does not think it is necessary to use the number of at risk days because ATSDR assumed that exposure was occurring every day for six years; the day exposure began based on sampling to the day Well 313 was closed. The determination of at risk days would have depended on the relative water levels of the shallow aquifer and Edwards Aquifer. When the water level in the Edwards Aquifer was below the top of the pipe connecting Well 313 and Well 314, the drinking water supply would be considered at risk. If we used the Bexar index well J-17 contrary to our discussion above, there were 3,249 days or 8.9 years "at risk" from 1932 when water elevation recordings began through January 31, 1989, the date Well 313 was taken out of service. The majority of the "at risk" days were in the 1950s during a major drought. From January 31, 1959 through January 31, 1989, a thirty year period, there were 1,054 days or 2.9 years at risk. ATSDR use of 6 years of exposure is halfway between these two values.

B. Reviewer Number 2
Comment: Yes

Response:
No response is needed.

C. Reviewer Number 3
Comment:
Conclusions - Yes
Recommendations - There were none. This is appropriate, given that the exposure occurred in the past, steps have been taken to eliminate additional exposure to on site populations and because the exposure was of relatively low magnitude and short duration.

Response:
No response is needed.

6. Are there any other comments about the public health consultation that you would like to make?

A. Reviewer Number 1

Comment: Yes

The lack of any demographic data regarding the population at risk makes it difficult to put this assessment in context. How many on-base workers? Average duration of employment on-base (are we talking months or years? How many children at childcare centers or on base housing? Average duration of residency?).

Response:

A total of 33,000 civilians worked for one year or more at Kelly AFB between 1981 and 2000. Duration of longest employment was 30+ years. The breakdown of employment is shown in Table F-1.

In 1980, the base population was 2,675 with 257 children under 5 years. In 1990, the population was 1,802 with 151 children under 5 years. In 2000, the base population increased to 1,939 with 200 children less than 5 years old. The population breakdown is shown in Table F-2.

During the 1980s (the leak in the pipe was found in 1989), Kelly AFB operated two childcare facilities on-base. They were located in Building 61 near the intersection of General Hudnell Drive, Billy Mitchell Road, and Duncan Drive and in Building Annex 140 located on S. Crickett Drive across from Lindberg Park. Annex 140 closed about 7 years ago and the Kelly Field Child Development Program in Building 61 is still operating. Building 61's capacity is 160 children; Annex 140's capacity was about 100 children.[1]

The wells closest to Building 61 in the 1980s were Wells 3010, 314, 313 in order of increasing distance (shortest distance first).[2] Annex 140 sits between Wells 313/314 and 81 and is adjacent to Well 141. Before it was closed in 1984, Well 141 pumped water in amounts similar to Wells 313 and 314. VOCs were detected in Well 3010 three times out of twelve samples (Table 3) with all values below the screening value or MCL (the MCL for trihalomethanes was used for chloroform).

The closest well to Billy Mitchell Village, the main housing area, was Well 1638. VOCs were detected in Well 1638 three times out of twelve samples (Table 3) with all values below the screening value or MCL (the MCL for trihalomethanes was used for chloroform).

[1]Leti Cuellar, Assistant Director, Kelly Field Child Development Center, August 2, 2003. Personal communication.

[2]Kelly AFB, Environmental Management, December 17, 1998. Water wells and water storage tanks.

The closest well to a particular location does not mean it provides a majority of the water. The amount of contribution is a function of water supply and demand throughout the system, and the layout of the distribution system. ATSDR does not know how much water each well contributed to the childcare facility because these factors were not evaluated. This information is not needed for the current consultation, however because ATSDR assumed that the concentration of contaminants in the water was a result of water mixing from Wells 313 and 314 alone, as water from these wells mixed before discharge into the distribution system, and that everyone was exposed to this water. The concentrations measured and predicted are shown in the following table:

Drinking water exposure concentrations (μg/L) based on different scenarios

Chemical	**Maximum VOC concentrations detected in Wells 313 and 314 and subsequent mixing of water from these two wells** (μg/L)	**Maximum VOC concentrations in shallow aquifer leaking and mixing with water from Well 313 and then with Well 314** (μg/L)		**Screening Value** (μg/L)	
		10 gallons per minute leakage rate	**50 gallons per minute leakage rate**	MCL	Modified EPA RBC‡
Chloroform	7.8	Not analyzed*		80†	8c 61nc
1,2-dichloroethane	26.8§	Not detected in shallow aquifer		5	6c 17nc
Tetrachloroethylene (PCE)	3.8	3.26	5.57	5	55c 250nc
Trichloroethylene (TCE)	Not detected	1.21	1.42	5	80c 35nc

* Not analyzed because the maximum concentrations were below the MCL and equal to the modified EPA Region 6 Risk Based Concentration (RBC) in the shallow aquifer.
†No MCL exists for chloroform. This MCL is for trihalomethanes, which consist primarily of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
‡ The EPA Region 6 Risk Based Concentration (RBC) value of 0.12 (μg/L) was modified from 30 years to 6 years of exposure and from a risk of 1 in 1,000,000 to 1 in 100,000 and includes exposure via ingestion and inhalation.
§ This is equivalent to 1.6×10^{-5} cancer risk based on exposure to a child for 28 months via ingestion and incidental inhalation (e.g. inhalation of vapors offgassing from the water during showering).

The only chemical exceeding a screening value above is tetrachloroethylene (PCE). The MCL for PCE shown above, 5, is based on the potential to cause cancer from long term exposure. The drinking water level considered "safe" for short-term exposure for children (assuming a 10 kg

[22 lb] child who consumes 1 liter of water per day) is 1 mg/L (i.e., 1000 μg/L) up to seven years of exposure.[1] Hence, even if this water were used at the childcare facilities, it is not likely to pose a health hazard.

Prenatal exposures have been a concern in the scientific literature. Such exposures would apply to those in on-base housing at Kelly AFB, or anywhere on-base where a pregnant woman consumed tap water. A 1998 ATSDR study at Camp Lejeune evaluated the prenatal exposures to tetrachloroethylene. The epidemiological study found possible associations of health effects from prenatal exposures. Although neural tube defects and major heart defects were seen in one case at a concentration greater than 10 μg/L, the odds ratios were not statistically significant for exposure greater than 5 μg/L. The study also noted a statistically significant increase in oral clefts in mothers exposed to concentrations greater than 10 μg/L. No association between tetrachloroethylene exposure and fetal deaths was found. The study did associate PCE exposure, however, with "small for gestational age" infants and mean-birth-weight difference. As of 2003, ATSDR is planning additional epidemiological studies at Camp Lejeune with a larger number of potentially exposed individuals and a water distribution study to determine potential exposure levels at each home.

The odds ratio for small-for-gestational-age infants at Camp Lejeune was slightly significant with the mean difference of -24 grams.[2] However, a study in northern New Jersey indicated no association between PCE and small-for-gestational-age infants.[3] The detection limit of tetrachloroethylene in water in the Camp Lejeune study was 10 μg/L in some cases, and the maximum concentration estimated was 215 μg/L, indicating that exposure at Camp Lejeune was much greater. Therefore, the predicted concentrations at Kelly AFB were below the levels associated with health effects in the Camp Lejeune study.

[1] U.S. EPA, November 26th, 2002. Technical Fact sheet on Tetrachloroethylene. http://www.epa.gov/safewater/dwh/t-voc/tetrachl.html [accessed August 5, 2003].

[2] Sonnenfeld N. Volatile Organic Compounds in Drinking Water and Adverse Pregnancy Outcomes. Interim Report. United States Marine Corps Base Camp LeJeune, North Carolina. Atlanta, GA:Agency for Toxic Substances and Disease Registry, 1998.

[3] Bove, Frank, Youn Shim, and Perri Zeitz. Drinking Water Contaminants and Adverse Pregnancy Outcomes: A Review. Environ Health Perspect. 2002 Feb;110 Suppl 1:61-74.

B. Reviewer Number 2

Comment:

1. The top line on page 8 requires editorial work. The second clause makes no sense.
2. Maps and figures are well done and notations and explanations are adequate and useful.
3. Tabulated data is clearly presented and footnotes are, for the most part clear. I recommend that the notations for (x/x) and (x/x) (in Table 3) be changed in some way to make them more distinctly different. Perhaps parenthesize only one of the ratios.
4. Appended materials are useful and Appendix D is quite interesting.

Response:
The sentence on page 8 was corrected.

The notation in Table 3 for the number of detects above EPA Risk Based Concentration at six years of exposure at 1/100,000 risk compared to the number of detects was identified by bold type. This notation has been clarified by using parentheses for the number of detects per number of samples collected {(x/x)}. Brackets and bolding were used for the number of detects above the EPA Risk-Based Concentration (six years of exposure at 1/100,000 risk compared to the number of detects) {**[x/x]**}.

C. Reviewer Number 3
Comment:
This document is short and succinct and does an adequate job of assessing past exposures to drinking water.

Response:
No response is needed.

7. Are there any comments on ATSDR's peer review process?

Comments:
Reviewers 1 and 2: No
Reviewer Number 3: The process seems fair and objective.
Response:
No response is needed.

8. Are there any other comments?

Comments:
Reviewers 1, 2, and 3: No
Response: No response is needed.

Table F-1. Characteristics of Kelly AFB Civilian Employees–1981 through 2001.

	Number	Percentage
Total employees	31,811	100.0
Total person-years	562,221.3	100.0
Age at hire (yrs)		
25	15,659	49.2
25–34	9,885	31.1
35	6,267	19.7
Gender		
Male	22,525	70.8
Female	9,286	29.2
Race/Ethnicity		
White, non-Hispanic	11,797	37.1
White, Hispanic	17,201	54.1
Black, non-Hispanic	2,417	7.6
Black, Hispanic	58	0.2
Other	338	1.1
Year of hire		
1969	12,209	38.4
1970–1989	17,843	56.1
1990	1,759	5.5
Duration of employment (yr)		
10	7,118	22.4
10–19	9,219	29.0
20–29	7,082	22.2
30+	8,392	26.4

Mundt, Diane J. PhD *et al.* Cause-specific mortality among Kelly Air Force Base civilian employees, 1981–2001. J Occup Environ Med 2002;44(11):989–96.

Table F-2. Residential Population at Kelly AFB.

	1980[*]	1990[†]	2000[‡]
Tract Identification Number[§]	48029161402	48029161485	48029161402
Total Population	2675	1802	1939
Persons Under 5 Years	280	174	250
Persons 5–9 yr	257	151	200
Persons 10–14 yr	204	102	125
Persons 15–17 yr	88	40	40
Persons 18–19 yr	230	150	103
Persons 20 yr	164	145	125
Persons 21 yr	153	99	138
Persons 22–24 yr	341	244	241
Persons 25–29 yr	370	310	273
Persons 30–34 yr	231	135	193
Persons 35–44 yr	266	159	199
Persons 45–54 yr	65	50	40
Persons 55–59 yr	14	35	8
Persons 60 and 61 yr	2	0	1
Persons 62–64 yr	4	8	0
Persons 65–74 yr	4	0	3
Persons 75–84 yr	2	0	0
Persons 85+ yr	0	0	0

* CensusCD 1980(tm). Version 1.0. GeoLytics, Inc. March–July 1999.

† CensusCD+Maps(tm). Version 2.5 (1990 Census). GeoLytics, Inc. July 1999.

‡ Bureau of the Census. Washington, DC: US Department of Commerce. [Accessed 2003 July 16]. Available at URL: http://factfinder.census.gov/servlet/DTTable?_ts=73833063488.

§ Kelly AFB's census tract number changed between 1980 and 1990. The change was identified through the MABLE '98/Geocorr v3.0 Geographic Correspondence Engine. [Accessed 2003 July 16.] Available at CIESIN at URL: http://plue.sedac.ciesin.columbia.edu/plue/geocorr/.