Health Consultation

PUBLIC COMMENT RELEASE

Surface Water, Sediment, and Biota Human Exposure Pathway Analysis for
Churchill County

FALLON LEUKEMIA PROJECT

FALLON, CHURCHILL COUNTY, NEVADA

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Introduction and Statement of Issues

In March 2001, the Nevada State Health Division (NSHD) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Center for Environmental Health (NCEH) evaluate environmental risk factors that might be linked to children who had developed leukemia in the area of Fallon, Churchill County, Nevada. ATSDR was asked to evaluate releases of hazardous substances in the county, and to provide an assessment of ways in which people in the community could be exposed to the substances. NCEH was asked to develop and conduct a cross-sectional exposure assessment of selected substances using environmental (household) and biological specimens for families of the children and for a reference population [1].

ATSDR and NCEH developed a public health action plan to investigate ways in which people could be exposed (i.e., environmental pathway analysis) [1]. Environmental pathway analysis is the study of the movement of contaminants in environmental media that will aid us in determining whether people could be exposed. Environmental media include groundwater, air, surface water, sediment, soil, and biota. Because of the large amount of work involved in conducting an environmental pathway analysis for an area such as Churchill County, ATSDR divided its pathway analysis into segments according to environmental media and locations. The pathway analyses address the following specific elements.

- JP-8 fuel pipeline
- Fallon Naval Air Station
- Churchill County air quality
- Churchill County surface water, sediment, and biota
- Churchill County soil and dust contaminants

This health consultation addresses the investigation of potential exposure to contaminated surface water, sediment, and biota in the Churchill County area of Nevada. Other environmental media are addressed in separate ATSDR documents. Appendix A is a list of ATSDR documents for Churchill County. In this health consultation, ATSDR evaluated available information on the hazardous substances found in the area's supply and drainage canals as well as those found in the area's rivers and reservoirs. ATSDR reviewed information collected by the US Geological Survey, the US Fish and Wildlife Service, the US Environmental Protection Agency (EPA), and the Nevada Division of Environmental Protection.

Background

Environmental information for this health consultation is grouped into two categories and discussed separately in the following sections. The categories are surface water system description and description of available environmental data (sediment, surface water, and biota).

1. Surface water system description

Churchill County lies within the 4,000 square-mile Carson River Basin, which is one of 14 hydrographic basins in western Nevada. Portions of the watershed extend across the state line into California. The watershed can be described by two integrated surface water features, Carson River in the Carson River Basin and the Newlands Irrigation Project structures.

Aquifer recharge comes primarily from snowmelt in the higher altitudes of Sierra Nevada and Pine Nut Mountain. The major stream in the basin is the Carson River, which flows about 180 miles through five hydrographic areas (Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley and LahontanValley). The Lahontan Reservoir, which is about 18 miles west of Fallon on the Carson River, is the only large storage reservoir in the Carson River Basin in Nevada. This reservoir stores surface water from the natural flow of the Carson River as well as surface water diverted from Truckee River by way of the Truckee Canal. From the Lahontan Reservoir, Carson River flows north and southeast to its natural terminus—the Carson Desert hydrographic area, which covers about 2,000 square miles in Churchill County. This area includes the city of Fallon, the Fallon Naval Air Station, Stillwater, the Fallon National Wildlife Refuge, Carson Lake, the Stillwater Wildlife Management Area, the Stillwater National Wildlife Refuge, the Carson Sink, and the Newlands Project irrigation area (Figure 1) [2–3].

The Newlands Project is a large-scale irrigation project started during the early 1900s by the Bureau of Reclamation for agricultural irrigation in the lower Carson River Basin near Fallon. The Newlands Project in Churchill County is shown in Figures 2 and 3. Major water works in the project include 4 dams, 6 reservoirs, and 758½ miles of canals and drains, as well as other water works [4–5].

Dams: Lahontan, Lake Tahoe, Carson River Diversion, and Derby Diversion

The Lahontan Dam, which is on the Carson River at the north end of the Lahontan Reservoir, was completed in 1915. The Lake Tahoe Dam, completed in 1913, regulates the outflow from Lake Tahoe into the Truckee River. The Carson River Diversion Dam, which is on the Carson River 5 miles below the Lahontan Dam, diverts water into two main canals. The Derby Diversion Dam on the Truckee River diverts water into the Truckee Canal.

Reservoirs: Lahontan, Shecker, S-Line, Old River, Harmon, and Stillwater Point

The Lahontan Reservoir, with a storage capacity of 314,000 acre feet, stores water from the natural flow of the Carson River along with water diverted from the Truckee River by way of the Truckee Canal. Five regulating reservoirs (Shecker, S-Line, Old River, Harmon, and Stillwater Point) further control flow through the extensive canal system described below and to wetlands (Carson Lake and Stillwater wetlands).

Canals

The Newlands Project has built 758½ miles of canals and drains. The Truckee Canal, which connects the Truckee River and the Carson River from Derby Diversion Dam to Lahontan Dam, is 32½ miles long. The length of the main Carson diversion canals (the T-Line and V-Line canals) is 69 miles. There are 312 miles of lateral canals such as the A-Line, D-Line, L-Line, S-Line, Extension Canal, Diagonal Canal, Stillwater Diversion Canal, Swope Canal, and Paiute Diversion Canal. The drainage system contains about 345 miles of deep, open-type drainage canals that return water to the Carson River, Carson Lake, and the wetlands of the Stillwater Wildlife Management Area and the Stillwater National Wildlife Refuge.

Other Works

Other works of the Newlands Project include the Lahontan power plant, the V-Canal power plant, and the power distribution system, which has 73 miles of transmission lines.

2. Available environmental data description

The US Geological Survey (USGS) collects water, sediment, and animal tissue samples from across the nation and analyzes the samples for their chemical, physical, and biological properties. ATSDR obtained Churchill County water quality data from the USGS National Water Information System for the period from 1956 to 1999. This information comes from different national programs such as the Drinking Water Program, the National Irrigation Water Quality Program, the National Stream Quality Accounting Network, and the National Water-Quality Assessment Program. Water quality data are collected for contaminants such as volatile organic compounds (VOCs), metals, pesticides, and nutrients [6].

EPA maintains surface water quality information for the nation's water that is collected by federal, state, and local agencies; Indian tribes; volunteer groups; academic institutions; and others. ATSDR retrieved surface water data for Churchill County from the STORET legacy data center, which stores data supplied to EPA before 1999. Sampling data provided by STORET included the date each sample was collected, the location and medium, sampling and analytical methods, and quality control checks [7].

The National Pollutant Discharge Elimination System Permit Program (NPDES) is designed to control water pollution by regulating point sources that discharge pollutants into waters of the United States. The Nevada Division of Environmental Protection issued NPDES permits to 30 facilities (Table 1) in Churchill County including the City of Fallon, the Fallon Naval Air Station, and some small dairies [8]. ATSDR reviewed available discharge monitoring reports that provided discharge locations and volume, sampling locations, and analytical parameters such as metals, nutrients, and microbiological agents.

Since the early 1970s, the USGS, US Fish and Wildlife Service, EPA, the Nevada Division of Environmental Protection, and the University of Nevada have conducted various studies to determine the extent of surface water and sediment contamination and levels of contaminants in fish, ducks, and other biota materials in the Carson River Basin and in the area of the Newlands Irrigation Project. ATSDR reviewed the following available documents:

- Total mercury in water, sediment, and selected aquatic organisms, Carson, River, Nevada [9]
- Pharmacokinetics of methyl mercury bioaccumulation in carp [10]
- Total mercury in sediment, water, and fishes in the Carson River drainage, west central Nevada [11]
- Detailed study of irrigation drainage in and near wildlife management areas, west central Nevada [12]
- Mercury in fish collected from the Indian Lakes system, Stillwater Wildlife Management Area [13]
- Mercury characterization in Lahontan Valley wetlands [14]
- Draft Ecological Risk Assessment, Carson River mercury site [15]
- Field screening of water quality, bottom sediment, and biota associated with irrigation in and near the Indian Lakes area, Stillwater National Wildlife Management Area, Churchill County, west central Nevada [29]
- Sources and impacts of irrigation drainwater contaminants in arid wetlands [30]
- Toxicity of striped bass (*morone saxatilis*) and *daphnia magna* [31]

ATSDR's Evaluation Process

Whether a person will be harmed by exposure to hazardous substances depends on several factors, including the type and amount of the contaminant; the way the person was exposed; the length of time the person was exposed; the amount of the contaminant absorbed by the body; site-specific conditions; genetic factors; and individual lifestyle factors. ATSDR provides public health advice on the basis of a review of toxicological literature, a comparison of levels of environmental contaminants detected at a site to published comparison values, an evaluation of potential exposure pathways and duration of exposure, and the characteristics of the exposed population.

ATSDR uses different comparison values (chemical-specific, health-based standards and guidelines) derived by various government agencies to screen contaminants and identify those that could require further evaluation of their potential to cause adverse health effects. While concentrations at or below the relevant comparison values might reasonably be considered safe, concentrations above these values will **not** necessarily cause harm. ATSDR uses site-specific exposure scenarios and performs an in-depth evaluation for substances detected at concentrations above the screening values.

ATSDR used the following comparison values for this health consultation: the environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), cancer risk evaluation guides (CREGs), minimal risk levels (MRLs), the EPA drinking water maximum contaminant levels (MCLs), EPA Region 9 preliminary remediation goals (PRGs), and the US

Food and Drug Administration action levels for poisonous or deleterious substances in human food and animal feed.

Discussion

ATSDR reviewed and evaluated the available environmental data for sediment, surface water, biota, flooding issues, and for environmental data limitations and gaps. These data are summarized and discussed in the following sections. Table 2 shows the dates and sources of the environmental data.

Sediment Data

From 1973 to 1999, USGS collected sediment samples at 88 sampling locations throughout Churchill County. Samples were taken from Carson River, Carson Lake, and Carson Sink, as well as the Newlands Irrigation Project areas such as Lahontan Reservoir, Truckee Canal, and the main and lateral delivery canals and drains. Samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), metals, pesticides and related compounds, as well as nutrients. Of the 137 substances analyzed, 82 different substances (60%) were detected. None of the sample analyses indicated the presence of VOCs in sediment. ATSDR reviewed the detected chemicals after grouping them into categories of metals, pesticides and related compounds, and SVOCs. Table 3 provides a summary of the chemicals detected in sediment.

Metals

In all samples collected in the Fallon area (that is, all samples taken at or downstream of the Lahontan Reservoir), 37 metals were detected. With the exception of arsenic and mercury, the levels of the detected metals were below their applicable comparison values. Therefore, only arsenic and mercury will be discussed further.

Arsenic is a naturally occurring element with an average concentration of 2–5 parts per million (ppm) in the earth's crust. Arsenic is therefore present at low levels in soil, water, food, and air. Because of natural factors of geology and climate, levels of arsenic in soil and other surface materials in Nevada are elevated compared to the national average [16]. The maximum level found for arsenic in Churchill County is 100 ppm.

Arsenic was found in 72 sediment samples evaluated for Churchill County, including 22 samples from the Fallon area. The highest concentration of arsenic detected was 680 ppm; the average concentration was 81.1 ppm. The ATSDR chronic EMEG for a child is 20 ppm; for an adult, it is 200 ppm. Those concentrations are considered to be safe levels for people exposed to arsenic for more than one year on a daily basis [17]. However, the most likely way that people would be exposed to arsenic in sediment at the site is through occasional ingestion of contaminated sediment or through infrequent dermal contact with contaminated sediment while participating in recreational activities or working. This kind of infrequent exposure to sediment containing arsenic is not likely to result in any adverse health effects.

Mercury also occurs naturally in several forms and, at very low levels, is typically found in the environment. For the Carson River drainage basin of west central Nevada, the background mercury concentration in sediment and soil ranges from 0.1 ppm to 1.6 ppm [18]. In the late 1800s, mercury was imported to the area to be used in gold and silver mining operations. Numerous mining operations along the Carson River Gorge area discharged an estimated 7,500 tons of mercury, primarily in the form of mercury-contaminated tailings, into the Carson River drainage basin [18]. The average concentration of mercury detected in sediment samples was 323 ppm. The highest concentration of 13,100 ppm was detected at the Stillwater slough cutoff drain in 1998 (Table 3). It appears that (1) the sediment concentrations of mercury increase with distance downstream from the sites of the early mining operations and (2) levels of mercury and other metals in sediment samples have increased over time [17–20]. The most likely exposure to mercury in sediment at the area is occasional ingestion or infrequent dermal contact with contaminated sediment by people who are participating in recreational activities or working. Infrequent exposure is not likely to cause any adverse health effects. However, mercury in sediment can enter and accumulate in the food chain (for example, in fish and other wildlife). Therefore, human consumption of mercury-contaminated fish or other food could result in exposure. The biota exposure pathway is discussed in a separate section of this document.

Pesticides and related compounds

The sediment samples were analyzed for 38 pesticides and related compounds. Of these, 14 (37%) were detected at very low concentrations (11 in the Fallon area). All of the detected chemicals were at concentrations below their applicable comparison values.

Semivolatile organic compounds

Semivolatile organic compounds (SVOCs) such as phenols, phthalate esters and polycyclic aromatic hydrocarbons (PAHs) were analyzed in nine sediment samples and found at concentrations below their applicable comparison values (Table 3). There were 31 chemicals detected at very low concentrations (nine in the Fallon area). The most frequently detected SVOCs were 2,6-dimethylnaphalene (maximum concentration of 0.12 ppm); di-(2-ethylhexyl) phthalate (maximum concentration of 0.55 ppm); diethyl phthalate (maximum concentration of 0.02 ppm); and di-n-butyl phthalate (maximum concentration of 0.07 ppm).

Surface Water Data

From 1956 to 1999, USGS and EPA collected surface water samples at 198 sampling locations throughout Churchill County including the Carson River, Carson Lake, and Carson Sink, as well as the Newlands Irrigation Project areas such as the Lahontan Reservoir, Truckee Canal, and the main and lateral delivery canals and drains. Samples were analyzed for pesticides and related compounds, metals, and other inorganic substances, VOCs, and SVOCs. Of the 284 substances analyzed, 79 (28%) were detected. Table 4 provides a summary of chemicals detected in surface water. ATSDR also reviewed and evaluated documents related to water quality in the Churchill County area and the National Pollutant Discharge Elimination System Permit Program.

Pesticides and related compounds

Twenty six pesticides and related compounds were detected at very low concentrations (11 in the Fallon area). Only two chemicals, p,p'-dichlorodiphenyldichloroethylene (p,p'-DDE), average concentration of 152 parts per billion (ppb), and gamma-hexachlorocyclohexane (lindane), average concentration of 0.10 ppb, were found at concentrations above their respective comparison values (Table 4).

Metals and other inorganic substances

More than 1,000 surface water samples were analyzed for metals and metalloids. Thirty-one metals were detected in most of the surface water samples (28 in the Fallon area). Five metals exceeded their respective comparison values. Those metals were (1) aluminum, with an average concentration of 10,200 ppb; (2) arsenic, with an average concentration of 54.5 ppb; (3) beryllium, with an average concentration of 0.80 ppb; (4) lead, with an average concentration of 12.1 ppb; and (5) mercury, with an average concentration of 297 ppb.

Only one recent study—which has limited information—was found on tungsten in Eastern Sierra Nevada rivers (the Truckee, Walker, and Carson Rivers). Surface water samples were collected at 12 locations along the Carson River from the East Fork to the Lahontan Reservoir. Trace elements analyzed for this study included boron, molybdenum, tungsten, and vanadium. Study results indicated that (1) Carson River and the other two rivers have relatively high concentrations of the selected trace elements including tungsten; (2) the upper reaches of the Carson River have higher levels of tungsten than the lower reaches; and (3) relatively high concentrations of the selected trace elements reflect a combination of processes such as weathering of rocks with high concentration of those elements.

Nineteen other inorganic substances including nitrate, nitrite, cyanide, phosphate, and sulfate were detected in many surface water samples (25 in the Fallon area). All of the detected chemicals were found at concentrations below their applicable comparison values.

Volatile organic compounds and semivolatile organic compounds

Only one SVOC, di (2-ethylhexyl) phthalate, with a maximum concentration of 5 ppb, was found in one surface water sample. Trans-1,3-dichloropropene and methyl isobutyl ketone were two VOCs detected with concentrations of 5 ppb and 10 ppb, respectively. All were at concentrations below their applicable comparison values.

All comparison values used to evaluate the surface water data are those established for drinking and tap water. These comparison values are based on conservative assumptions and default exposure factors such as water ingestion rates (2 liters per day for adults and 1 liter per day for children); exposure frequency (350 days per year for residents); and exposure duration (30 or 70 years for adults, 6 years for children). For the site-specific exposure scenarios, the surface water in Churchill County was classified as Class C water. Class C water is "located in areas of moderate-to-urban human habitation, where industrial development is present in moderate amounts, agricultural practices are intensive and where the watershed is considerably altered by man's activity. The beneficial uses of class C water are municipal or domestic supply, or both, following complete treatment, irrigation, watering of livestock, aquatic life, propagation of wildlife, recreation involving contact with the water, recreation not involving contact with the water, and industrial supply" [21].

The most likely human exposure at the site is occasional ingestion and/or infrequent dermal contact with contaminated surface water by persons participating in recreational activities or work. This kind of infrequent exposure to the contaminated surface water is not likely to result in any adverse health effects. Some metals such as mercury in surface water can enter and accumulate in the food chain (for example, fish and other wildlife). Therefore, human consumption of contaminated fish or other wildlife could result in exposure. The biota pathway is discussed in a separate section of this document.

Water quality documents

ATSDR also reviewed documents related to water quality in the Carson River Basin, the Carson Desert agricultural area, and in the irrigation-drain systems of the Newlands Irrigation Project [2–4, 22–23]. Findings from these studies include the following.

- The primary sources of nutrients, synthetic organic compounds, and trace elements are urban activities. Concentrations of most constituents vary with season and streamflow.
- Agricultural areas have contributed pesticides, nutrients, trace elements, and dissolved solids to the water resource through irrigation drainage.
- Historical mining activities and natural factors of geology and climate caused high concentrations of dissolved solids, arsenic, mercury, and other elements in this area.
- The average concentration of nutrients in the Carson River was lower than the national median. However, nutrients were enriched in the Carson River downstream from the Carson Valley and Carson Desert.
- Pesticides were present at low levels in agricultural areas, but were found at lower levels than the national median.

National Pollutant Discharge Elimination System Permit Program

The Nevada Division of Environmental Protection (NDEP) issued National Pollutant Discharge Elimination System permits to 30 facilities in Churchill County including the City of Fallon, the Fallon Naval Air Station, and some small dairies. ATSDR reviewed selected discharge monitoring reports, which contain information on discharge locations and volume, sampling locations, and analytical parameters such as metals, nutrients, and microbiological agents.

The City of Fallon and Kennametal are the biggest point sources of wastewater and are of community concern in the Fallon area. The City of Fallon municipal waste water treatment plant discharges to New River Drain. Samples taken from three locations were analyzed for flow, PH, total dissolved solids, total suspended solids, percentage of suspended solids removal, biochemical oxygen demand, percentage of biochemical oxygen demand removal, total nitrogen, total phosphorus, coliform bacteria, and free and residual chlorine. No significant levels of tested chemicals were observed from available discharge monitoring reports. Kennametal discharges waste water to groundwater via approved leach fields consisting of double lined evaporation ponds. The discharge volume is 10,750 gallons per day. Chemicals tested at the main septic system include iron, magnesium, manganese, copper, zinc, fluoride, calcium, sodium, beryllium, arsenic, chloride, silica, boron, sulfate, nitrate and total dissolved solids. No significant levels of tested chemicals were observed from available discharge monitoring reports.

Biota Data

Mercury is the primary contaminant of concern for bioaccumulation and biomagnification in the food chain for Churchill County. Since the early 1970s, several studies have been conducted on fish, ducks, algae, and other wildlife species in the Carson River Basin and the area of the Newlands Irrigation Project. Samples of more than 36 species of wildlife were analyzed for mercury concentrations in different tissues. Wildlife samples include 18 species of fish, 5 species of duck and 2 non-duck bird species, 4 species of benthic invertebrates, and other biota such as algae, corixid, detritus (bottom sediment containing mostly organic debris), lizards, and zooplankton.

Mercury concentrations in fish tissues ranged from less than 0.02 ppm to 11 ppm, wet weight. Mercury concentrations in 112 composite drift samples (containing algae, submerged vascular plants, detritus, corixids, brine flies, and other organic materials) ranged from less than 0.04 ppm to 97.8 ppm, dry weight. For the five species of duck, mercury concentrations ranged from less than 0.5 ppm to 38.9 ppm, wet weight. The average mercury concentrations in duck muscle and liver were 5.9 ppm and 17.8 ppm, respectively. Other major findings of biota studies are summarized in the following paragraphs [9–15, 29–31].

- Mercury was derived from the historical mining activities upstream of the Carson River, transported during high streamflow (flooding events) before the construction of the Lahontan Reservoir (1915). Most of the mercury deposited in Carson Lake, the Stillwater Wildlife Management Area, the mouth of the Carson River in Carson Sink, and along the floodplain of the river. Mercury remains biologically available and can be bioaccumulated within the area.
- The probable mercury contamination pathway in biota appears to be as follows: fluvial sediment transport to bottom sediment; from bottom sediment to bottom–dwelling biota (invertebrates, algae, plants, and forage fish); and from the biota to waterfowl.
- Most of the total mercury in corixids, a representative aquatic invertebrate, existed as methyl mercury, the form of mercury that can accumulate in the food chain. In swallows tested for mercury contamination, more than 90% of the total mercury detected existed as methyl mercury.
- Bioaccumulation factors for methyl mercury from sediment to corixids ranged from less than 100 to more than 2,000 in wetlands of the Stillwater National Wildlife Refuge and the Fallon National Wildlife Refuge.

- Within irrigation drains, mercury is being bioaccumulated in plants and plant detritus and biomagnified in vertebrates by factors up to 10,000 times the concentrations measured in associated drainwater.
- The irrigation system, especially drainage canals, has redistributed mercury throughout Lahontan Valley.

Table 5 provides a summary of all available biota data for total mercury concentrations in Churchill County.

Although most of the mercury found in the environment is in the form of metallic mercury and inorganic mercury compounds, microorganisms convert inorganic mercury to methyl mercury. Methyl mercury can accumulate in the food chain and is also most easily absorbed by the human body. Inorganic mercury does not accumulate in the food chain to any extent [24]. Therefore, health-related comparison values used in this document are for methyl mercury only.

On the basis of the study results [11] and the Food and Drug Administration's action level for methyl mercury in the edible portion of fish and duck (1 ppm, wet weight), the Nevada State Health Division issued area health advisories for the consumption of fish and duck. The duck advisory was for the consumption of northern shoveler (*Anas clypeata*) harvested in the area of Carson Lake. The fish advisory was for all fish caught from Dayton to the Lahontan Dam of the Carson River and from all waters in the Lahontan Valley area. The following chart provides additional information on the health advisories.

Pollutant	**Species**	**Area Affected**	**Year Issued**	**Type Issued**	**Status**
Mercury	Carp/blackfish	Lahontan Reservoir	1982	CFB	Rescinded
Mercury	All fish	Lahontan Reservoir	1986	RCGP/RCSP	Rescinded
Mercury	Duck (shoveler)	Carson Lake	1989	RCGP/RCSP	Unknown
Mercury	All fish	Carson River	1993	NCGP/NCSP	Active
Mercury	All fish	Lahontan Valley	1994	NCGP/NCSP	Active

Blackfish: Sacramento blackfish
CFB: commercial fishing ban
RCGP: restricted consumption advisory for the general population
RCSP: restricted consumption advisory for sensitive subpopulations
NCGP: no consumption advisory for the general population
NCSP: no consumption advisory for sensitive subpopulations
Carson River: Dayton to the Lahontan Dam

ATSDR established a minimum risk level (MRL) of 0.0003 milligrams per kilogram per day for chronic exposure (more than 365 days) to methyl mercury. The MRLs are estimates of daily human exposure to mercury that are likely to be without an appreciable risk of adverse health effects. The chronic MRL for methyl mercury is based on a no-observed-adverse-effect level (NOAEL) for neurodevelopment effects in humans, with an uncertainty (safety) factor of 4.5 (3 for human variability and 1.5 modifying factor of the selected study). Organic and inorganic mercury are not known to be carcinogenic by the oral ingestion route [24].

Because fish and duck consumption rates for Churchill County are not available for this evaluation, ATSDR used the EPA intake recommendations for recreational freshwater anglers (8 grams per day, 8.5 ounces per month, 6.4 pounds per year) and other very conservative assumptions (Appendix A) to calculate the estimated maximum concentration of total mercury that could result in exceeding the respective MRL [25]. Based on the risk evaluation, a mercury concentration in fish of 2.6 ppm would result in an exposure exceeding the MRL. The most current data indicated mercury in 5 species of fish (channel catfish, white catfish, white bass, large mouth bass, and walleye) and 2 species of duck (shoveler and green-winged teal) exceeded 2.6 ppm. Therefore, consumption of mercury-contaminated fish and duck poses a potential public health hazard, especially for young children and pregnant women. However, realistic site-specific exposure scenarios as listed below could significantly reduce exposure to methyl mercury:

(1) The estimated mean fish intake for the general population is lower than that for recreational freshwater anglers.
(2) Posted health advisories in the Lahontan Valley area could minimize the residents' intake of fish and duck.
(3) The total mercury concentrations are the sum of inorganic and organic mercury compounds. The true methyl mercury concentrations should be lower than those used for the risk evaluation.
(4) The average concentrations of total mercury should be lower than the maximum concentrations of total mercury that were used to calculate the estimated safe level.
(5) The absorption and bioavailability of methyl mercury in food may be affected by other dietary components such as dietary fiber, phytate, and selenium.

Please refer to Appendix B for intake assumptions and dose calculations.

ATSDR contacted the local office of US Fish and Wildlife Service, Bureau of Indian Affairs, Indian Health Services, and the Fallon Paiute Tribe and confirmed that tribe-specific fish and wildlife consumption rates are not available. However, in general, fish and wildlife consumption rates for Native Americans are higher than that for the general population [25]. Therefore, tribe members may have a higher exposure from consumption of mercury-contaminated fish and wildlife.

While biomagnification in the aquatic food chain is well studied, data are limited for the potential biomagnification or bioconcentration of mercury and other metals in the terrestrial food chain (that is, local crops and livestock such as alfalfa, melons, cattle, and milk) [24]. The Carson River is the source of drinking water for some local livestock, and it is the source of water for irrigating local crops and pastures. Consumption of mercury-contaminated, locally produced dairy products, meat, fruits, and vegetables may represent another route of human exposure to mercury and other contaminants.

There are limited biota data on other trace metals in the Churchill County area. In addition to mercury, analyzed trace metals include aluminum, arsenic, boron, fluoride, selenium, uranium, and zinc. Selenium is another metal having significant biomagnification in the aquatic food chain. However, concentrations of selenium in edible portions of selected waterfowl samples were below the level of human health concern [12]. Arsenic can be picked up by some fish and sellfish, however, most arsenic in the fish tissues is in an organic form (arsenobetaine or "fish arsenic"), which does not appear to be harmful to humans and is excreted rapidly in urine [17].

Flooding

There are community concerns about a major flood that occurred in 1997 in the Carson Valley. Community members want to know whether the flood could have some link with the occurrence of acute lymphocytic leukemia in the Fallon community. The movement of water is a significant force in redistributing chemicals in the environment. Water and sediment from floods can be points of environmental exposure. Pollutants can travel dissolved in water or attached to particles that move with water. Particles in water come mostly from the bottom of the river or lake or from runoff discharged into the waters.

Water moving at a higher velocity than normal (as in flooding) has a greater capacity to carry more particles, suspend particles that were previously at the bottom of the river or lake, erode shorelines, and potentially move greater amounts of pollutants. Smaller particles need lower water velocities than larger particles to stay suspended. On a per mass basis, more pollutants adsorb onto smaller particulates because of their greater surface area. When water enters a slow-moving area such as a lake or a pooled area of a stream, the larger particles tend to settle out. Stagnant areas, such as areas of receeding floodwater, can receive sediment deposits in a wide range of particle sizes, including the smaller particles. Deposited sediment could contain pollutants, and people could be exposed to them through direct contact. Furthermore, these pollutants could volatilize into air or move into the groundwater where again people could be exposed to them through other routes such as inhalation and ingestion.

For dissolved pollutants, complex relationships exist between the concentration in the water and the total amount of the pollutant moving downstream. During flooding events, dissolved pollutants could occur at lower concentrations because of the greater amount of water for dilution while the total amount of the pollutant mass moving downstream may be the same. However, greater amounts of water may cause the pollution source to increase its contribution to water.

Flooding is part of the natural hydrologic cycle and hydrography in a watershed. In Fallon, the hydrography has been significantly altered by the Newlands Irrigation Project, a large-scale irrigation project started during the early 1900s by the Bureau of Reclamation for agricultural irrigation in the lower Carson River Basin near Fallon. The project infrastructure consists of dams, canals, drainage ditches, and reservoirs. The Truckee-Carson Irrigation District operates the Newlands Project and its infrastructure. As a normal course of operation, agricultural fields in Fallon are irrigated with a surface/gravity type of irrigation. In a way, this method is a form of controlled flooding. These controlled flooding activities occur at least annually on most active agricultural fields in Fallon. A true flood, however, is not controlled by humans; flooding occurs when surface water spills over the banks and shorelines of rivers and lakes inundating buildings and land. Both types of flooding are important in the transport of pollutants in the environment. Because of the concerns of people in the Fallon community, this section will focus on flooding from nonirrigation activities.

To evaluate this flooding as a potential point of exposure, ATSDR conducted the following activities:

- Reviewed USGS stream gaging data
- Interviewed people in the community
- Reviewed floodplain maps
- Reviewed newspaper articles
- Reviewed historical satellite images

USGS stream gaging station data

USGS routinely monitors stream flow at 10 stream gaging stations in Churchill County with 2 stations on the Carson River. Gage station number 10312150 (Figure 4) is located in the Carson River below the Lahontan Reservoir and is the most appropriate gaging station for evaluating stream flow in the Carson River and in the irrigation canals that run through Fallon. While the community specified concerns about the 1997 flood, ATSDR also noted even greater peak flow in June 1983, June 1986, June 1995, and May 1996. Figure 5 provides additional information about the station's annual peak stream flow and the highest values for gage flow rate from 1980 through 2000. Records about the flow events that were higher than that of the January 1997 flood are shown in the following table.

Records of Gage Station 10312150, Carson River, Below Lahontan Reservoir

Record Date	Gage Height (feet)	Flow rate (cubic feet per second)
6/22/1983	8.22	3100
6/6/1986	5.78	2330
6/30/1995	7.27	2150
5/17/1996	7.74	2440
1/7/1997	7.0	2020

From this data, ATSDR decided to evaluate the 1997 event and the three other flow events that had peak gage heights greater than that in 1997 (June 1983, June 1995, May 1996).

Interviews

ATSDR discussed the community's concerns about flooding with Lyman McConnell (Truckee Carson Irrigation District, Project Manager), Steve Endecott (City of Fallon, Emergency Management Coordinator), Mike Wargo (Churchill County Mosquito Abatement District, Manager), the Nevada State Department of Health, and one resident. The general information provided by the state and local government officials is that a large amount of flooding occurred upstream of the Lahontan Reservoir and in Carson City and Reno, Nevada, in 1997. However, the 1997 flooding that occurred downstream of the Lahontan Reservoir was controlled by the diversion of the water from the Carson River to the irrigation and drainage canals and to regulatory reservoirs (including the Harmon, S-Line, and Sheckler Reservoirs). Water was also allowed to spill out from the Carson River Diversion Dam to the north and from the Sheckler Reservoir to the south. The water eventually drained to Carson Lake and the Stillwater Wildlife Management Area. Farmers were requested to flood their fields at this time. Minimal property damage occurred in 1997 except for damage reported in the Bafford Lane area northeast of Fallon.

The resident whom ATSDR interviewed lives on property that borders the South Branch of the Carson River. Because of the irrigation system, the south branch is now a drain and is not connected to the Carson River. The front part of the resident's property, which includes the house, is located in the 500-year flood boundary, and the back portion of the property is located in the 100-year flood boundary. The house and front yard are elevated above the backyard by a gentle slope that dips about 5 feet towards the river. The resident remembers that in the 1983 flood, the water rose almost to the top of the slope but did not flood the house. In the 1995 flood, the backyard and the backyards of the adjoining properties were covered with a thick blanket of silt. Although water levels also rose during the high water events in 1996 and 1997, they were not as high as those in 1983 or 1995.

Floodplain Maps

ATSDR digitized flood maps from the Federal Emergency Management Agency (a list of the maps is provided in Appendix C) and overlaid them on maps showing the property parcels of the case houses (houses associated with children diagnosed with leukemia). Two of those house property parcels are located within but at the edge of the 100-year flood zone and one house is located within but at the edge of the 100-year to 500-year flood zone (Figure 6).

Newspaper Articles

ATSDR reviewed historical newspaper articles from the local community newspapers dated back to 1983. The articles reviewed were from the *Lahontan Valley News* and the *Fallon Eagle Standard.*

Most articles indicated that the biggest flood occurred in 1983 and the critical area affected by floods was the Bafford Lane area. The 1997 flood had minimal impact in the Fallon area. For example, during the 1983 event, about 14–25 properties were affected; in the 1995 event only one property was reported to be affected; no properties were reported as affected in the 1996 and 1997 events. The articles also indicated that after the 1983 flood, farmers were requested to release water into their fields during periods of high water.

Historical Satellite Images

ATSDR reviewed satellite images acquired from the US Landsat Program for 1983, 1993, 1995, 1996, and 1997 to determine whether this data could confirm the information from the interview and the historical newspaper articles. The dates of those images were chosen to be as close as possible after the peak discharge dates. The 1993 image is considered a base low flow event

(854 cubic square feet) [27].Two images were obtained for 1997 because the June 7, 1997, image, the day of the peak flow, only covered half of Fallon area while the June 16, 1997, image covered the entire Fallon area, but was 9 days after the peak flow. Appendix D provides technical information for the Landsat images.

Because of the relative low resolution of the images and the difficulty in distinguishing vegetation from shallow water covering vegetation, ATSDR was only able to make qualitative statements about the images. From this review, ATSDR identified that the reservoirs and lakes were much fuller during the flood events than during the low flow periods.

The Carson River appears to be "fullest" in 1983 and much less full in 1995, 1996, and 1997. The 1995 event appears to have been the second "fullest" event, followed by 1996 and 1997. The 1983 image indicates that the Carson River formed small "pools" (an indication of flooding) along the river's course north of Fallon. Because of the satellite resolution, the main canals can barely be distinguished in the images and the secondary canals and drains cannot be distinguished. In the 1995 and later images, canals were seen as one or two pixels wide, with each pixel equal to 30 meters. The 1983 image had a resolution of 60 meters, and therefore the canals in the 1983 image were barely discernable.

From the review, ATSDR determined that the satellite images showed that none of the case houses appeared to have been inundated with water. However, the images showed that water in pools was potentially present near several of the case houses.

- A house for one case is in a subdivision adjacent to fallow and farmed land. In the 1996 flood event, a pool of water apparently formed on the fallow land and on the farm land. The closest water was about 800 feet from the house.
- A house for one case is located about 800 feet south of the Carson River and about 700 feet from the V-Line Canal. The house was built in 1995. In the 1983 image, the field between the house and the river appears to be covered with water. The land where the house sits may also have been flooded. No flooding was evident in the other Landsat images for the other years.
- A house for one case is located about 220 feet from the V-Line canal and about 1,100 feet from the Upper West Side Drain. The house was built in 1945. In the 1995 flood event, a pool of water apparently formed around the drain about 1,000 feet from the house.
- A house for one case is located about 150 feet from a branch of the A-Line Canal and about 500 feet from the Upper West Side Drain. Pooling of water in an adjacent field and into the drain may have occurred in 1996 (approximately 500 feet from the house). A date of housing construction was not in the parcel database, but the house was probably constructed prior to 1994 based on the aerial photograph.
- A house for one case is located approximately 380 feet from the L-Line canal. The property lot may have a low spot that collects water during these flooding events or may be somehow connected to the L-Line. The house was constructed in 1991. Images from 1995, 1996, and 1997 indicate that water may have been present approximately 300 feet from the house.

The locations of the case and control houses in this review were based on addresses matched to the addresses in the Churchill County parcel map. If the parcel map did not have a corresponding case/control house address, the house address was manually matched using the US Census Bureau digital street maps [28]. ATSDR also used 1994 digital aerial photography obtained from the Bureau of Reclamation. A qualitative estimate of error of the mapped house locations is about 0.2 miles. With up-to-date aerial photographs (several of the case houses were not yet built in 1994) or geographic positioning system locations, ATSDR can reduce this error to within a few yards which would improve the analysis.

In summary, the 1997 flood had minimal impact in the Fallon area. The previous floods in 1983, 1995, and 1996 were more significant. The 1983 flood had the most impact in Fallon, followed by the 1995 flood. Little property damage occurred from these floods. The most impacted area was the Bafford Lane area northeast of Fallon. There was no case house in this area.

Persistent environmental contaminants such as mercury and other contaminants from upstream (e.g., the EPA Superfund site, the Carson River mercury site) are transported downstream by the Carson River and associated canals and drains. During historical flooding events, larger amounts are probably transported and ultimately deposited in Carson Lake, the Stillwater Wildlife Management Area, and the braided canals of the Carson River near and in the Carson Sink, the floodplain of the river, and the farmers' fields open to irrigation at the time. Farmers who flooded their fields during the high water events and areas of minor flooding (as reported by the resident) received more suspended sediments from the water. Overall, the irrigation system and the drainage canals have redistributed mercury throughout Lahontan Valley.

The flooding events in Fallon are not likely to be direct exposure points based on the location of the houses. However, ATSDR cannot determine the past activities of the people in the area and therefore cannot determine whether they would have come in contact with the sediment outside their houses. Furthermore, the movement of the pollutants in the sediment could volatilize into the air (for example, mercury) or move into the groundwater (for example, arsenic). ATSDR addressed the air and groundwater pathways in separate documents.

Environmental data limitation and gaps

Available environmental data for this evaluation are subject to limitations affecting the interpretations made from the data.

- Environmental samples reviewed were collected for purposes not related to public health. For example, these data were collected in area hydrology summaries, general water quality assessments, and for federal and state regulation compliance monitoring.
- The involvement of multiple agencies including USGS, EPA, state and local governments, and the municipal water treatment plant may result in great differences in field collection techniques, sample-preservation methods, sampling frequency, and laboratory analytical methods. These differences make comparison of data sets difficult.
- Environmental samples were taken over a long period of time (1956–1999). Detection method and technology changes and improvements over time could result in overestimating or underestimating the true value of data.

- Samples were not analyzed for all possible contaminants; only limited analytes were selected. For example, of 190 pesticides used in Nevada, only 68 were analyzed for in a pesticide study. Only one sample was analyzed for acrolein (Magnacide®), a herbicide used for vegetation control in irrigation canals.
- Limited samples were taken from the Fallon area where the majority of Churchill County's residents live. For example, very few sediment samples were taken within a 5-mile radius of the center of Fallon.
- Information for biota exposure pathways was limited to selected chemicals (for example, mercury and selenium) and wildlife species (mainly fish and ducks). There is insufficient data on consumption rate of fish, duck, and other wildlife species as well as consumption rate and contamination of locally produced dairy products, meat, fruits, and vegetables.

Conclusions

On the basis of the available information, ATSDR concludes the following:

Human consumption of mercury-contaminated fish and duck poses a potential public health hazard, especially for young children and pregnant women for long-term exposures. Total mercury concentrations of five species of fish (channel catfish, white catfish, white bass, large mouth bass, and walleye) and two species of duck (shoveler and green-winged teal) exceeded the estimated concentration of 2.6 ppm that could result in an exposure exceeding the chronic methyl mercury MRL.

Infrequent exposure to the contaminated sediment is not likely to result in any adverse health effects. Thirty-seven metals, 14 pesticides, and 31 semi-volatile organic compounds were detected in sediment samples. All of the detected chemicals, with the exception of arsenic and mercury, were at concentrations below their applicable comparison values.

Infrequent exposure to the surface water is not likely to result in any adverse health effects. Twenty-six pesticides and related compounds, 50 metals and other inorganics, 2 volatile organic compounds, and l semi-volatile organic compound were detected in surface water samples. All of the chemicals detected in the surface water samples, with the exception of 5 metals (aluminum, arsenic, beryllium, lead, and mercury) and 2 pesticides (p,p'-DDE and lindane), were present at concentrations below their applicable comparison values.

The 1997 flood had minimal impact in the Fallon area. The flooding events in Fallon are not likely to be direct exposure points based on the location of the houses (both cases and controls). Persistent environmental contaminants such as mercury and other contaminants from upstream were most likely transported during the historical flooding events, and deposited in Carson Lake, the Stillwater Wildlife Management Area, the mouth of the Carson River in Carson Sink, the floodplain of the river, and the farmers' fields open to irrigation at the time. The irrigation system and the drainage canals have redistributed mercury throughout Lahontan Valley.

Recommendations

- Minimize the intake of mercury-contaminated fish and duck through comprehensive approaches such as health education, fish and wildlife consumption surveillance, and a wide distribution of information related to the Nevada State Health Division health advisories on human consumption of fish and duck in the Lahontan Valley area.
- Although occasional exposure to the contaminants in surface water and sediment in the Carson River, reservoirs, lakes, and canals is not expected to result in adverse health effects, concerned persons could reduce the potential for exposure by cleansing skin and washing clothing after contact with surface water and sediment.

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Table 1. NPDES Permitted Facilities in Churchill County

Name	Address	NPDES No	EPA ID	SIC Code
A&A Dairy	3550 Tarzyn Road	NVA000001	000008055004	0241
Amor IV Corp	5500 Soda Lake Road	NVU000041	NV0000736165	NA
Bar-Bell Farms	7770 Flying K Lane	NVU000016	000008054094	NA
Beagle Holsteins	3500 Trento Lane	NVA000004	000008055034	0241
Clever Dairy	3105 Fischer Place	NVA000006	000008054308	0241
Cottonwood Dairy	640 W Corkill Lane	NVA000007	000008054318	0241
Diamonte Jerseys	5550 Bottom Road	NVA000009	000008055338	0241
Fallon, City of	1575 Wood Dr.	NV0020061	NVD000334235	4952
Forest Farms	7770 Flying K Ranch Lane	NVA000003	000008055024	0241
Gomes Ranch	3025 Allen Road	NVA000012	000008054368	0241
Guazzini Dairy	3855 Austin Highway	NVA000013	000008054378	0241
Hillside Dairy	4170 Bass Road	NVA000014	000008054388	0241
Hollandia Dairy	340 N Harmon Road	NVA000015	000008054398	0241
Jernigan Dairy	Churchill County	NVA000016	000008054406	0241
Jernigan Ranch	NA	NVA000026	000008054406	0241
Liberty Jersey Farm	4624 Cox Road	NVA000017	000008054416	0241
Lorenzo Septage Site	Churchill County	NVU000066	000009906130	NA
Mills Jersey Farm	4675 Sheckler Road	NVA000020	000008054446	0241
Nunes Dairy	5255 Casey Road	NVA000022	000008054466	0241
Oxbow Geothermal Corp	Dixie Valley	NV0021407	NV0000017053	4911
Perazzo Dairy	1025 Perazzo Lane	NVA000023	000008054476	0241
Pine Grove WWTF	Latin Road	NV0022799	NV0001950633	1629
Regli Dairy	1240 Soda Lakes Road	NVA000025	000008054496	0241
Sorenson Dairy	4720 Schurz Highway	NVA000029	000008054534	0241
Southfield Dairy	1750 Strasdin Lane	NVA000030	000008054544	0241
Star L Dairy	2200 Lone Tree Road	NVA000031	000008054554	0241
Travis Dairy	1950 Wade Lane	NVA000033	000008054574	0241
Triangle Dairy	4800 Allen Road	NVA000034	000008054584	0241
US Navy	Naval Air Station Fallon	NV0110001	NV9170022173	9711
Whitaker Dairy	2295 Sorensen Road	NVA000035	000008054594	0241

SIC codes:
0241: dairy farm; 1629: heavy construction; 4911: electric services
4952: sewerage system; 9711: national security; NA: not available

Table 2. Summary of Environmental Data

Media	Source	Start Date	End Date
Sediment	US Geological Survey	1973	1999
Surface water	US Geological Survey US Environmental Protection Agency National Pollutant Discharge Elimination System	1956	1999
Biota	US Geological Survey Nevada Department of Environmental Protection US Fish and Wildlife Service US Environmental Protection Agency	1971	1999

Table 3. Summary of Detected chemicals in Sediment Samples for Churchill County (in parts per million)

	Chemical	Maximum	Mean	Detects/ sample	CV	CV Type
Halogenated Pesticide or Related Compound	9,10-ANTHRACENEDIONE	0.0544	0.0544	1/9	NA	NA
	ALDRIN	0.0003	0.0003	1/25	0.04	CREG
	CHLORDANE, TECHNICAL	0.045	0.0128	4/17	2	CREG for chlordane
	CIS-CHLORDANE	0.00077	0.00077	1/9	2	CREG for chlordane
	DDD, P,P'-	0.0032	0.000883	6/30	3	CREG
	DDE, P,P'-	0.0021	0.000593	15/29	2	CREG
	DDT, P,P'-	0.0002	0.0002	3/28	2	CREG
	DIELDRIN	0.0046	0.00112	5/26	0.04	CREG
	HEPTACHLOR	0.0001	0.0001	1/25	0.2	CREG
	HEPTACHLOR EPOXIDE	0.0005	0.00035	2/26	0.08	CREG
	HEXACHLOROCYCLOHEXANE, GAMMA-	0.0047	0.0025	3/26	0.44	PRG
	METHOXYCHLOR	0.001	0.001	1/26	10	RMEG
	POLYCHLORINATED BIPHENYLS	0.006	0.004	2/26	0.22	PRG
	TRANS-CHLORDANE	0.0008	0.0008	1/9	0.44	PRG
Metals	ANTIMONY	76	3.72	68/68	31	PRG
	ARSENIC	680	81.1	72/72	0.5	CREG
	BARIUM	1,200	787	68/68	5,400	PRG
	BERYLLIUM	5.1	1.81	65/68	150	PRG
	BISMUTH	20	3.2	22/68	NA	NA
	BORON	140	80	4/4	5,500	PRG
	CADMIUM	1.9	0.463	63/38	10	EMEG
	CERIUM	89	55.2	67/68	NA	NA
	CHROMIUM	95	42.8	72/72	2,100	PRG for total chromium
	COBALT	240	38.4	68/68	4,700	PRG
	COPPER	400	66.8	68/68	2,900	PRG
	EUROPIUM	3.1	1.71	37/68	NA	NA
	GALLIUM	34	16.5	67/68	NA	NA
	HOLMIUM	2.6	1.5	23/68	NA	NA
	LANTHANUM	43	29.6	67/68	NA	NA
	LEAD	73	19.2	68/72	400	PRG
	IRON	18,000	14,000	4/4	NA	40 mg/day for children (UL)
	LITHIUM	100	31.3	72/72	1,600	PRG
	MANGANESE	7,000	1,300	72/72	1,800	PRG
	MERCURY	13,100	323	83/84	6,100	PRG for methylmercury
	MOLYBDENUM	430	15.8	59/72	3,900	PRG
	NEODYMIUM	51	27.1	67/68	NA	NA
	NICKEL	390	52.2	68/68	1,500	PRG
	NIOBIUM	18	7.54	61/68	NA	NA
	SCANDIUM	17	12.2	64/68	NA	NA

	Chemical	Maximum	Mean	Detects/ sample	CV	CV Type
	SELENIUM	9	1.31	68/72	10	CMEG
	SILVER	17	2.24	27/68	3,900	PRG
	STRONTIUM	2,300	640	68/68	47,000	PRG
	TANTALUM	2.1	1.4	3.68	NA	NA
	THALLIUM	8.7	4.68	20/41	520	PRG
	THORIUM	220	12.7	61/68	NA	NA
	TIN	11	2.38	39/68	47,000	PRG for inorganic
	URANIUM	173	9.08	68/68	16	PRG
	VANADIUM	320	136	68/68	550	SSL
	YTTERBIUM*	3.8	1.93	59/68	NA	NA
	YTTRI UM	47	18.3	67/68	NA	NA
	ZINC	290	112	68/68	600	CEMEG
Semi-volatile Organic Compound	METHYLPHENANTHRENE	0.0249	0.0249	1/9	NA	NA
	2,4,6-TRICHLOROPHENOL	0.077	0.077	1/1	60	CREG
	2,6-DIMETHYLNAPHTHALENE	0.12	0.0495	8/9	40	naphthalene RMEG for pica
	4H-CYCLOPENTA(DEF) PHENANTHRENE	0.0283	0.0283	1/9	NA	NA
	ACENAPHTHYLENE	0.014	0.014	1/9	NA	NA
	ANTHRACENE	0.0342	0.0342	1/9	600	RMEG
	BENZO(A)ANTHRACENE	0.0656	NA	1/9	NA	NA
	BENZO(A)PYRENE	0.0559	NA	1/9	0.1	CREG
	BENZO(B)FLUORANTHENE	0.0563	0.0563	1/9	0.62	PRG
	BENZO(GHI)PERYLENE	0.0311	0.0311	1/9	0.62	PRG
	BENZO(K)FLUORANTHENE	0.0554	0.0554	1/9	0.62	PRG
	BENZO{C}CINNOLINE	0.011	0.011	1/9	0.62	PRG
	BUTYL BENZYL PHTHALATE	0.0915	0.059	3/9	12,000	PRG
	CARBAZOLE	0.0295	0.0295	1/9	32	SSL
	CHRYSENE	0.0391	0.0391	1/9	62	PRG
	CRESOL, PARA-	0.77	0.193	6/9	310	PRG
	DI(2-ETHYLHEXYL)PHTHALATE	0.547	0.0899	9/9	50	CREG
	DIETHYL PHTHALATE	0.0216	0.0161	8/9	2,000	RMEG
	DI-N-BUTYL PHTHALATE	0.0748	0.0383	8/9	200	RMEG
	DI-N-OCTYL PHTHALATE	0.058	0.058	1/9	2,600	SSL
	FLUORANTHENE	0.087	0.087	1/9	80	RMEG
	INDENO(1,2,3-CD)PYRENE	0.0408	0.0408	1/9	0.62	PRG
	NAPHTHALENE	0.0064	0.0064	1/9	40	RMEG for pica
	PHENANTHRENE	0.0288	0.0288	1/9	7,800	SSL
	PHENOL	0.054	0.0275	5/9	1,000	RMEG
	PYRENE	0.0941	0.0941	1/9	60	RMEG

Data used in this table were obtained from the USGS National Water Information System and the EPA STORET legacy data center for the period from 1973-1999. Samples with results as not detect were not listed and were not used in statistics.

CREG: cancer risk evaluation guide for 1×10^{-6} excess cancer risk

RMEG: reference dose media evaluation guide
SSL: soil screen level
EMEG: environmental media evaluation guide
IEMEG: intermediate environmental media evaluation guide
CEMEG: chronic environmental media evaluation guide
CRMEG: chronic reference dose media evaluation guide
PRG: preliminary remediation goals
UL: tolerable upper intake level
LTHA: long term health advisory
NA: not available

Table 4. Summary of Chemicals Detected in Churchill County Surface Water Samples (in parts per billion)

	Chemical	Maximum	Mean	Detects/ sample	CV	CV type
Halogenated Pesticide or Related Compound	2,4-D, DISSOLVED	1.6	1.08	3/48	370	PRG
	AROCLOR 1242/1248/1260(void)	67,000	26,500	4/4	0.02	CREG
	ATRAZINE	0.18	0.18	1/2	400	RMEG
	ATRAZINE, DISSOLVED	0.18	0.0136	29/50	400	RMEG
	CARBOFURAN	0.035	0.0179	7/50	50	RMEG
	CHLORPYRIFOS DISSOLVED	0.006	0.006	1/50	10	PRG
	CYANAZINE	0.051	0.051	1/2	1	LTHA
	CYANAZINE, DISSOLVED	0.028	0.0158	4/50	1	LTHA
	DACTHAL	0.002	0.002	1/49	100	RMEG
	DDE, P, P'-	152	152	1/4	0.1	CREG
	DEETHYL ATRAZINE, DISSOLVED	0.036	0.0066	15/50	400	RMEG
	DIAZINON, DISSOLVED	0.032	0.021	2/50	33	PRG
	EPTC	0.042	0.0142	9/50	300	RMEG
	HEXACHLOROCYCLOHEXANE, GAMMA-	0.2	0.101	2/7	0.052	PRG
	LASSO (Alachlor)	0.041	0.041	1/2	0.84	PRG
	MALATHION, DISSOLVED	0.054	0.0406	3/50	200	EMEG
	METHOXYCHLOR DISSOLVED	0.02	0.02	1/1	NA	NA
	MET0LACHLOR, WATER, DISSOLVED	0.008	0.008	1/50	NA	NA
	METRIBUZIN, DISSOLVED	0.006	0.006	1/50	910	PRG
	NAPROPAMIDE	0.004	0.004	1/50	3,700	PRG
	PEBULATE	0.009	0.009	2/50	1,800	PRG
	PROMETON, DISSOLVED	0.058	0.0154	13/50	550	PRG
	PROPARGITE	0.003	0.003	1/50	730	PRG
	PROPAZINE	0.147	0.147	1/2	730	PRG
	SIMAZINE, DISSOLVED	0.11	0.00945	21/50	0.56	PRG
	TEBUTHIORON	0.0218	0.0218	1/50	2,600	PRG
	TERBACIL	0.009	0.009	1/50	470	PRG
Inorganic Substance	AMMONIA	29,000	913	294/297	30,000	LTHA
	AMMONIA NITROGEN	24,000	709	346/361	NA	NA
	BROMIDE DISSOLVED	290,000	45,800	8/20	NA	NA
	CARBON DIOXIDE DISSOLVED	32,000	2,630	213/213	NA	NA
	CHLORIDE DISSOLVED	6,200,000,000	567,000	1091/1099	NA	NA
	CYANIDE	262	262	1/1	700	RMEG
	FLUORIDE DISSOLVED	240,000	1,090	621/670	2,200	PRG
	HYDROGEN SULFIDE	130	130	1/1	100	RMEG
	IODIDE, DISSOLVED	9	7.5	2/2	NA	NA
	NITRATE	120,000	9,020	145/145	20,000	RMEG
	NITRATE DISSOLVED	10,500	1,240	187/187	20,000	RMEG
	NITRATE PLUS NITRITE (AS N)	13,000	594	174/186	NA	NA
	NITRITE	3,800	112	122/146	3,700	PRG
	NITRITE AS N, DISSOLVED	300	36.4	329/578	3,700	PRG
	NITRITE DISSOLVED	2,600	184	125/125	3,700	PRG
	NITROGEN AMMONIA DISSOLVED	24,000	380	743/882	NA	NA
	NITROGEN DISSOLVED	27,000	2,000	144/144	NA	NA
	NITROGEN NITRITE PLUS NITRATE DISSOLVED	9,300	340	481/734	NA	NA
	PHOSPHATE	2,000	673	67/67	NA	NA
	PHOSPHATE ORTHO DISSOLVED	30,000	1,580	283/283	NA	NA
	PHOSP HORUS	31,000	770	896/909	0.7	RMEG
	PHOSPHORUS, DISSOLVED	8,200	277	527/549	0.7	RMEG
	SILICA DISSOLVED	150,000	280	736/741	NA	NA
	SULFATE	102,000	37,000	25/25	NA	NA
	SULFATE DISSOLVED	64,000,000	541,000	868/871	NA	NA
	ALUMINUM	140,000	10,200	24/25	37,000	PRG
	ALUMINUM, DISSOLVED	190,000	2,670	201/278	37,000	PRG
	ANTIMONY	1	1	1/14	4	RMEG
	ANTIMONY, DISSOLVED	120	10.6	46/182	15	PRG

	Chemical	Maximum	Mean	Detects/ sample	CV	CV type
	ARSENIC	800	54.5	148/150	0.02	CREG
	ARSENIC, DISSOLVED	32,000	237	599/624	0.02	CREG
	ARSENIC, SUSPENDED	14	3.13	15/21	0.02	CREG
	BARIUM	1,600	164	34/45	2,600	PRG
	BARIUM, DISSOLVED	750	73	369/387	2,600	PRG
	BARIUM, SUSPENDED	400	86.4	14/14	2,600	PRG
	BERYLLIUM	1.9	0.795	6/26	0.016	PRG
	BERYLLIUM, DISSOLVED	17	3.99	24/245	0.016	PRG
	BORON	3,700	512	20/20	3,300	PRG
	BORON, DISSOLVED	1,300,000	7,920	596/603	3,300	PRG
	CADMIUM	30	2.18	22/60	18	PRG
	CADMIUM, DISSOLVED	4,000	74.9	58/382	18	PRG
	CADMIUM, SUSPENDED	29	12.5	4/11	18	PRG
	CALCIUM	46,000	27,200	11/11	NA	2,500mg/day UL
	CALCIUM, DISSOLVED	1,000,000	49,500	1011/1014	NA	2,500mg/day UL
	CHROMIUM	30	8.02	34/63	100	LTHA
	CHROMIUM, DISSOLVED	15,000	145	139/482	100	LTHA
	CHROMIUM, SUSPENDED	30	12.4	12/13	100	LTHA
	COBALT	268	17.5	35/52	2,200	PRG
	COBALT, DISSOLVED	3,100	337	39/272	2,200	PRG
	COBALT, SUSPENDED	40	12	5/13	2,200	PRG
	COPPER	270	20.6	61/72	1,300	MCLG
	COPPER, DISSOLVED	2,800	32.3	342/485	1,300	MCLG
	COPPER, SUSPENDED	120	17.8	29/31	1,300	MCLG
	IRON	140,000	5,500	84/84	11,000	PRG
	IRON DISSOLVED	1,100,000	9,890	419/438	11,000	PRG
	IRON, FERROUS	33.5	33.5	1/1	11,000	PRG
	IRON, SUSPENDED	40,000	6,660	18/18	11,000	PRG
	LEAD	120	12.1	43/72	15	Action level
	LEAD, DISSOLVED	130	10.7	84/390	15	Action level
	LEAD, SUSPENDED	120	21.4	15/25	15	Action level
	LITHIUM	120	76.7	6/6	7,300	PRG
	LITHIUM, DISSOLVED	8,500	165	546/559	7,300	PRG
	MAGNESIUM	10,000	6,900	10/10	NA	350 mg/day UL
	MAGNESIUM, DISSOLVED	1,400,000	28,600	988/991	NA	350 mg/day UL
	MANGANESE	6,650	534	61/61	500	RMEG
	MANGANESE, DISSOLVED	25,000	581	410/434	500	RMEG
	MANGANESE, SUSPENDED	1,500	188	31/31	500	RMEG
	MERCURY	23,800	297	380/443	110	PRG
	MERCURY ORGANIC	0.0218	0.00169	159/160	2	MCL
	MERCURY, DISSOLVED	50	0.659	123/390	110	PRG
	MERCURY, SUSPENDED	25	2.15	27/27	110	PRG
	MOLYBDENUM	940	121	15/29	1,800	PRG
	MOLYBDENUM, DISSOLVED	56,000	307	497/633	1,800	PRG
	NICKEL	562	32.2	35/37	7,300	PRG
	NICKEL, DISSOLVED	8,000	83.6	239/340	7,300	PRG
	NICKEL, SUSPENDED	6	3.14	7/7	7,300	PRG
	POTASSIUM	20,000	12,700	2/2	NA	NA
	POTASSIUM, DISSOLVED	2,600,000	17,600	913/914	NA	NA
	RUBIDIUM DISSOLVED	30	30	1/2	NA	NA
	SELENIUM	8.01	1.51	21/142	1,800	PRG
	SELENIUM, DISSOLVED	21	2.49	37/502	1,800	PRG
	SELENIUM, SUSPENDED	1	1	3/3	1,800	PRG
Metals	SILVER	8	2.83	12/38	50	RMEG
	SILVER, DISSOLVED	5	1.5	20/324	50	RMEG
	SILVER, SUSPENDED	8	3.8	5/5	50	RMEG
	SODIUM	78,000	35,600	11/11	NA	NA
	SODIUM, DISSOLVED	150,000,000	707,000	1066/1068	NA	NA
	STRONTIUM	876	366	15/15	6,000	RMEG
	STRONTIUM, DISSOLVED	1,800	443	135/136	6,000	RMEG
	THALLIUM, DISSOLVED	220	43	15/22	NA	NA

	Chemical	Maximum	Mean	Detects/ sample	CV	CV type
	TITANIUM	4.24	1.82	5/13	NA	NA
	URANIUM	1.1	0.598	9/13	30	MCL
	URANIUM, DISSOLVED	19,300	151	225/248	30	MCL
	URANIUM, NATURAL, 2 SIGMA	20	9.91	12/12	30	MCL
	VANADIUM, DISSOLVED	3,200	80.6	169/308	2,600	PRG
	ZINC	470	41	64/72	3,000	CEMEG
	ZINC, DISSOLVED	820	34.7	308/445	3,000	CEMEG
	ZINC, SUSPENDED	180	38	24/24	3,000	CEMEG
Radionuclide						
	ALPHA, DISSOLVED	420	50.3	59/62	NA	NA
Semivolatile organic compound						
	DI(2-ETHYLHEXYL)PHTHALATE	5	5	1/5	3	CREG
Volatile organic compound						
	1,3-DICHLOROPROPENE, TRANS-	5	5	1/6	1,000	CRMEG
	METHYL ISOBUTYL KETONE	10	10	1/2	160	PRG

Data used in this table were obtained from the USGS National Water Information System web site and the EPA STORET legacy data center for the period of from 1954-1999. Samples with results as not detect were not listed and were not used in statistics.

CREG: cancer risk evaluation guide for 1×10^{-6} excess cancer risk

RMEG: reference dose media evaluation guide

EMEG: environmental media evaluation guide

IEMEG: intermediate environmental media evaluation guide

CEMEG: chronic environmental media evaluation guide

CRMEG: chronic reference dose media evaluation guide

PRG: preliminary remediation goals

UL: tolerable upper intake level

LTHA: long term health advisory

NA: not available

MCL: maximum contaminant level

MCLG: maximum contaminant level goal

Table 5. Summary of Biota Data for Total Mercury in Churchill County, Nevada

Report Year	Source	Sample size	Number of species	No. of stations	Result Range (ppm)
1971	University of NV	200	7 (fish: white bass, etc.)	5	0.02–2.72 (wet weight)
1972	Richins et al.	not available	1 (fish: carp)	1	0.020–1.360 (wet weight)
1976	University of NV	not available	1 (fish: carp)	1	5.0–11 (wet weight)
1985	NDEP	333	18 (fish: channel catfish, white bass, black bullhead, yellow perch, Sacramento perch, Sacramento blackfish, walleye, white catfish, green sunfish, largemouth bass, bluegill, carp, rainbow trout, white crappie, Tahoe sucker, mountain sucker, speckled dace, Lahontan redside)	11	0.06–4.14 (wet weight)
1986	NDEP	not available	1 (fish: walleye)	1	1.85–5.23 (wet weight)
1989	NDEP	not available	1 (fish: white bass)	1	0.27–3.28 (wet weight)
1990	NDEP	not available	2 (fish: white bass, walleye)	1	0.33–4.77 (wet weight)
1992	USFWS	43	4 (fish: carp, white bass, white crappie, channel catfish)	5	0.5–2.7 (wet weight)
1992–94	USGS/USFWS/ USBR/USBIA			95	
	Biological pathways for mercury and selenium	112(composite)	1 (detritus)		<0.04–97.8 (dry weight)
		76	1 (algae)		<0.02–10.4 (dry weight)
		89	1 (detritus)		<0.04–38.6 (dry weight)
		87	1 (algae)		not tested for mercury
		55	1 (drift-algae, submergent vascular plants, detritus, daphnids, ostracods, amphipods, corixids, chironomids, brine flies, leeches, odonates)		not tested for mercury
		12	1 (brine fly)		not tested for mercury
	Mercury and selenium in edible tissue of waterfowl	161	4 (duck: Mallard, Redhead, Canvasback, Shoveler)		<0.5–38.9 (wet weight)
1996	USFWS		7 (pondweed, chironomid, corixid, tui chub, pumpkinseed, and carp)		<0.2–2.7 (dry weight)
1998	EPA (Lahontan Reservoir data only)			1	
		7	1 (zooplankton)		<0.5–2.7 (0.31 average)
		26	4 (benthic invertebrates-crayfish, caddisfly, midge larvae)		not available not available midge 0.05–0.2
		58	6 (fish: carp, green sunfish, mountain sucker, Sacramento blackfish, Tahoe sucker, walleye)		1.47 (whole body), 2.04 (muscle) average
		33	2 (birds: swallow, cormorant)		2.1–37 (wet weight)
		8	1 (lizard)		not available
1999	Mercury characterization in Lahontan Valley wetlands	68	1 (aquatic invertebrate- corixids)	43	<0.5–1.8 (dry weight)
		Total >1468			

Appendix A

List of ATSDR Documents for Churchill County

1. Pathway Assessment for Churchill County Surface Soil, Residential Indoor Dust, and Electromagnetic Fields

2. Air Exposure Pathway Assessment, Fallon Leukemia Cluster Investigation

3. Fallon Naval Air Station Evaluation of Potential Exposures from the Fallon JP-8 Fuel Pipeline

4. Public Health Assessment, Naval Air Station Fallon

5. Off-Target Drift of Pesticides from Aerial Application Human Exposure Pathway Analysis for Churchill County

Appendix B
Dose Calculations

ATSDR established acute (1–14 days) and intermediate (14–365 days) MRLs for inorganic mercury as 0.007 and 0.002 mg/kg/day, respectively. For chronic (more than 365 days) exposure, the MRL for methyl mercury is 0.0003 mg/kg/day. The MRLs are estimates of daily human exposure to mercury that is likely to be without an appreciable risk of adverse health effects over a certain time period. The acute and intermediate MRLs for inorganic mercury are based on the no-observed-adverse-effect level (NOAEL) for renal effects in rats, with an uncertainty factor of 100 for extrapolation from animals to humans and human variability. The chronic MRL for methyl mercury is based on the NOAEL for neurodevelopment effects in human, with an uncertainty factor of 4.5 for human variability and modifying factor of the selected study. Organic and inorganic mercury is not known to be carcinogenic by the oral ingestion route [24].

Although most of the mercury found in the environment is in the form of metallic mercury and inorganic mercury compound, microorganisms convert inorganic mercury to methyl mercury the form that can accumulate in the food chain. Methyl mercury is also the form of mercury most easily absorbed by the human body. Inorganic mercury does not accumulate in the food chain to any extent [24]. Therefore, the chronic MRL for methyl mercury is used to estimate exposure dose.

The following assumptions were made to estimate maximum concentrations that could result in exceeding chronic MRLs in edible portion of fish, ducks and other biota materials:

(1) The average intake of fish, duck and other biota materials for freshwater anglers is 8 grams per day (EPA exposure factors hand book), the average intake for children is 4 grams per day.
(2) The average body weight for adults is 70 kg and the average body weight for children is 10 kg.
(3) Total mercury concentrations were used as concentrations of methyl mercury.
(4) Fish and duck consumption is the major source of mercury intake from food and other sources.

The following mathematical formula was used to estimate maximum concentrations that could result in exceeding the MRL:

$$C_{max} = (IDf \times BW)/(CR \times EF)$$

Where:
Cmax = maximum concentrations that could result in exceeding the MRL in edible portion of fish, duck, and other biota materials in milligrams per gram (mg/g)
IDf = ingestion dose in mg/kg/day (respective oral MRLs for mercury)
CR = consumption rate of fish or duck or other biota materials (g/day)
EF = exposure factor (unitless—conservatively assumed to be 1.0)
BW = body weight (kg)

Therefore:
C max for chronic methyl mercury exposure (adult) = (0.0003 mg/kg/day × 70 kg)/ (8 g/day × 1) =0.0026 mg/g = 2.6 ppm

C max for chronic methyl mercury exposure (child) = (0.0003 mg/kg/day × 10 kg)/ (4 g/day × 1) =0.00075 mg/g = 0.75 ppm

Appendix C

List of FEMA Maps Digitized

Federal Emergency Management Agency National Insurance Program Flood Insurance Maps for Churchill County were digitized for spatial analysis. The following maps were digitized.

Name	Community Panel Number	Revised Date
City of Fallon, Nevada, Churchill County	320002 0001A	January 6, 1999
Churchill County, Nevada	320030 0001-1275	January 6, 1999
Churchill County, Nevada	320030 0645A	January 6, 1999
Churchill County, Nevada	320030 0665E	January 6, 1999
Churchill County, Nevada	320030 0850C	November 15, 1985
Churchill County, Nevada	320030 0855D	January 6, 1999

Appendix D

Satellite Image Information

Satellite	Resolution	Path/Row	Date
Landsat 4	60 meters	42/33	June 27, 1983
Landsat 5	30 meters	42/33	August 1, 1993
Landsat 5	30 meters	42/33	June 4, 1995
Landsat 5	30 meters	42/33	June 6, 1996
Landsat 5	30 meters	43/32	June 7, 1997
Landsat 5	30 meters	42/33	June 16, 1997

Figure 1. **Carson River Basin**

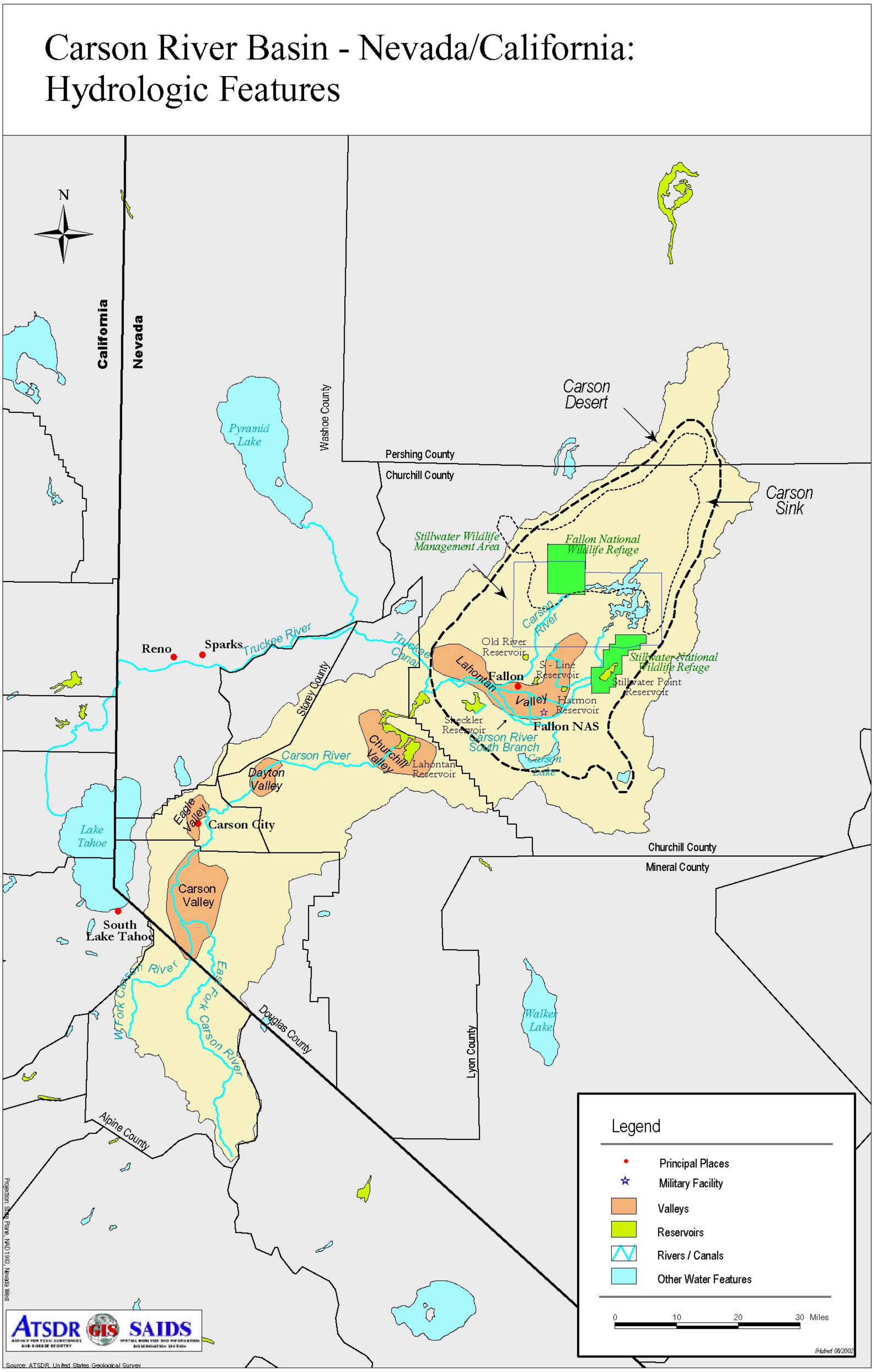

Figure 2. **The Newlands Project n Nevada and California**

Figure 3. **The Newlands Project in Churchill County, Nevada**

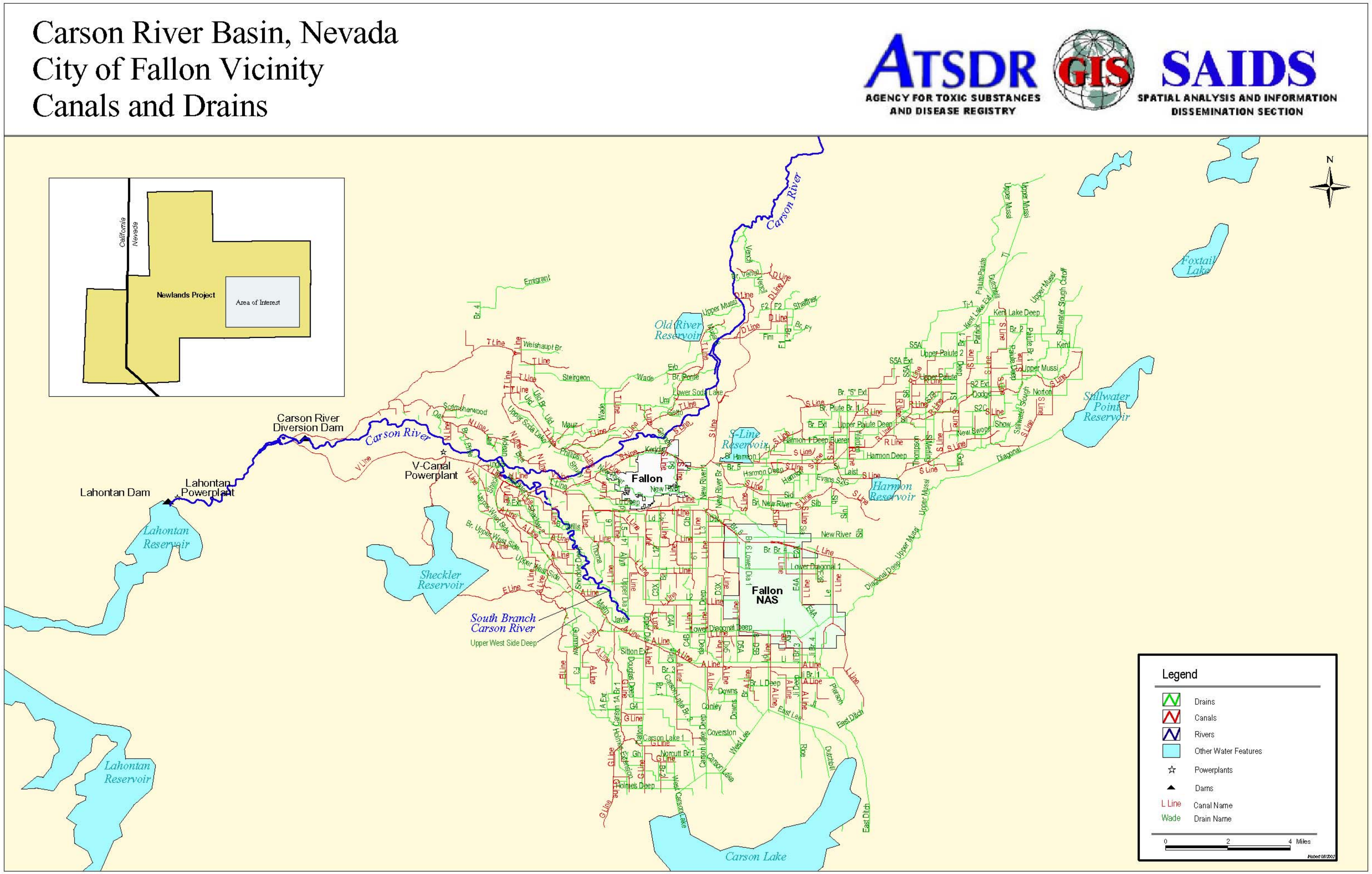

Figure 4. Gaging Stations in Churchill County, Nevada

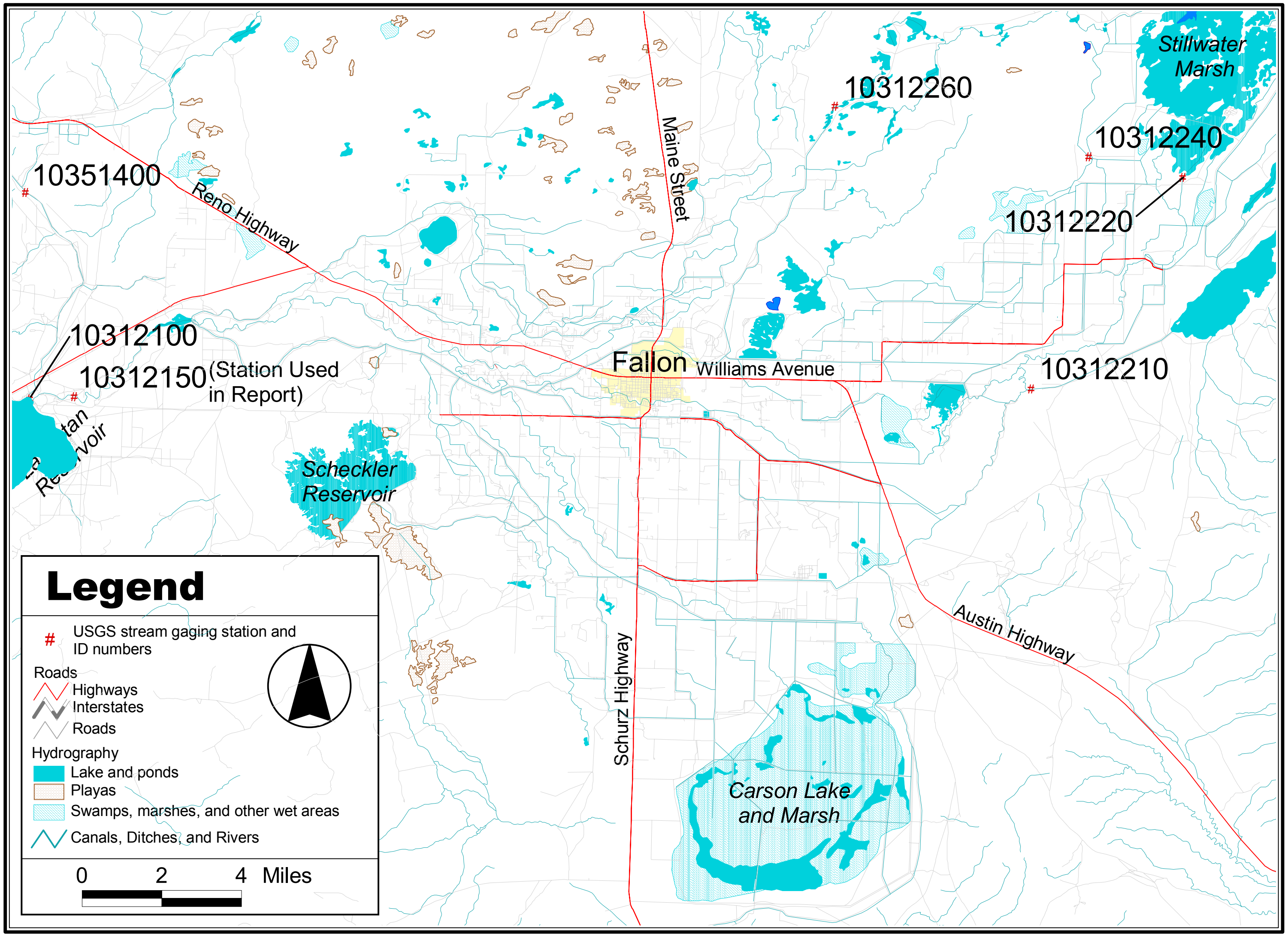

Figure 5. **Annual Peak Flow from 1980 Through 2000**

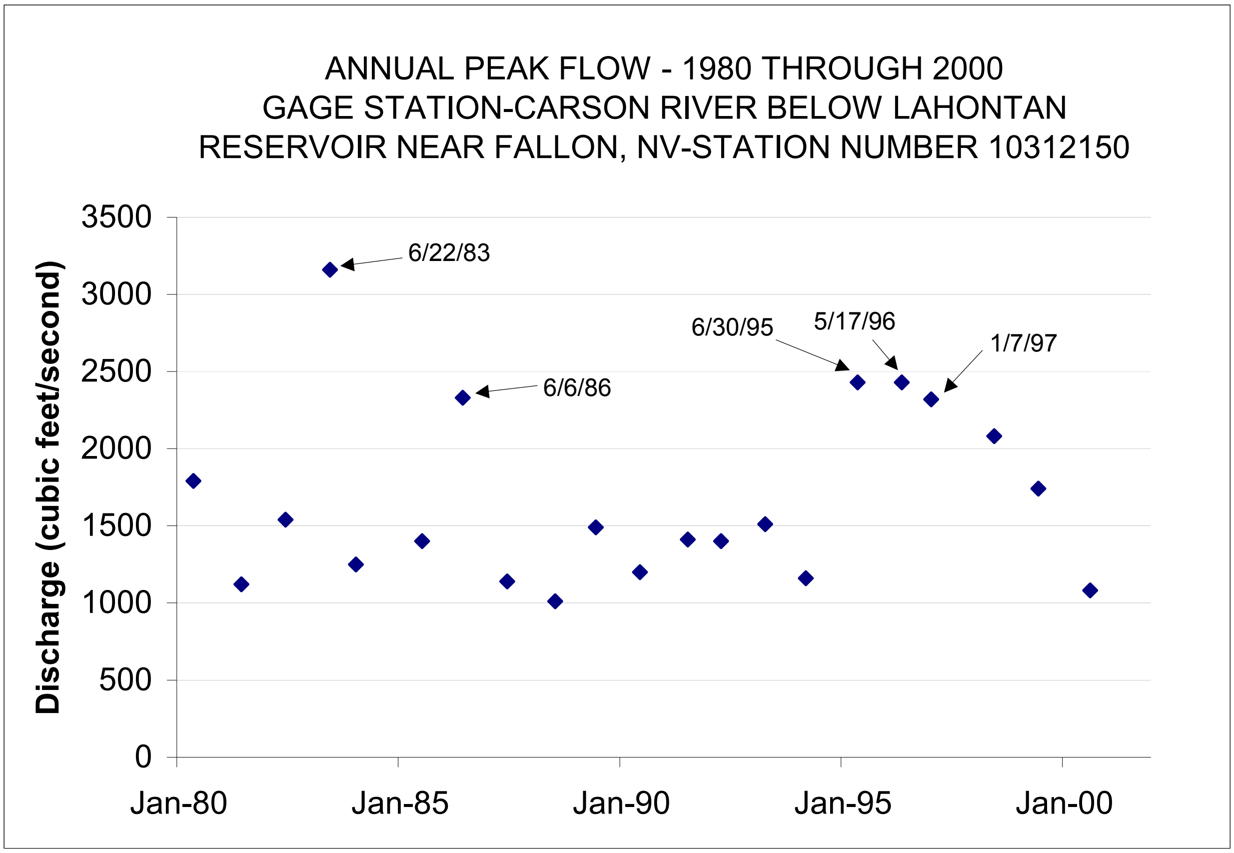

Figure 6. **Case and Control Houses and the Floodplain**