WATER QUALITY INVESTIGATION
RELATED TO THE LEUKEMIA CLUSTER
FALLON, NEVADA

U.S. Geological Survey
Water Resources Division
Nevada District Office

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EXECUTIVE SUMMARY

PROBLEM: A cluster of Acute Lymphocytic Leukemia (ALL) cases in the Fallon, Nevada area was identified during the summer of 2000. To date, thirteen children have been diagnosed with ALL, and an additional child has been diagnosed with Acute Myolitic Leukemia. One child has died. The Nevada State Epidemiologist convened a meeting April 17, 2001 of State and Federal agencies to address data needs for an investigation into potential causes of the cluster. USGS presented an overview of its published work in the Fallon area (http://nevada.usgs.gov/fallon/fallon.htm). Subsequent discussion focused on radioisotope work published in Open-File Report 94-31, as radiation has been linked to various forms of leukemia. A front-page article in the Reno Gazette-Journal the next morning focused on the USGS report and led to a request from the Nevada Congressional delegation to the Director of the USGS for an immediate study to quantify potential environmental vectors that might be related to the Fallon cluster.

This work plan is the USGS response to that request. The plan has been developed in consultation with the City of Fallon, Churchill County, the Nevada Health Division, the Nevada Division of Environmental Protection, the Nevada State Epidemiologist, the Centers for Disease Control, the Agency for Toxic Substances and Disease Registry, and the staffs of Senators Harry Reid and John Ensign and Representative Jim Gibbons. The time frame for the study is extremely compressed in order to meet the needs of the State and Federal agencies that require the data on an extremely tight schedule.

OBJECTIVES: This study has six objectives: (1) to characterize current chemical quality of all drinking water sources in the Fallon area; (2) to determine if there have been changes in water quality over the last decade; (3) to evaluate differences in water quality using a variety of statistical techniques; (4) to evaluate if water consumed by the case families differs from water consumed by the community as a whole; (5) to correlate water quality conditions with soil and dust analyses collected by the Nevada Division of Environmental Protection and with bioassay data collected by the Centers for Disease Control; and (6) to relate any identified correlations with the incidence of ALL..

RELEVANCE AND BENEFITS: The USGS was specifically requested by the Nevada Congressional Delegation to perform this study. Additionally, this study directly supports issues identified in the USGS Water Resources Discipline (WRD) strategic plan, the Strategic Directions for the WRD document, and the Nevada District Science Plan. While not being funded under the USGS Cooperative Water Program, several priority issues of that program are also addressed.

APPROACH: The first objective will be met through a stratified collection and analysis of ground water samples that are representative of current water quality conditions in the utilized aquifers. The stratification will include sampling wells that USGS has used as part of its National Water Quality Assessment Program, wells in residential areas that have been developed

since Open-File Report 94-31 was published, wells near where ALL case families have lived, and wells near a jet-fuel pipeline that many Fallon residents believe may be contributing contaminants to the drinking water supply.

The second objective will be met by comparing these current conditions to conditions previously published in several USGS and State agency reports. Maps will be produced showing concentration contours for key chemical constituents and showing areas where significant concentration changes have occurred.

The third objective will be met by analyzing the data using principal component and cluster analytical tools. Where appropriate, Stiff diagrams will be constructed to visually highlight ground water differences in the various aquifers. Where data exists, ground water will be age-dated.

The fourth objective will be met by analyzing differences between water quality at case family residences compared to water quality for non-case family residences in the same areas.

The fifth object will be met by integrating data collected by USGS and data collected by other participating agencies doing complementary media analyses. At present, the Nevada Division of Environmental Protection plans to collect and analyze soil and dust samples at case family residences and at control family residences. Similarly, the Centers for Disease Control is planning on sampling blood, urine, and tissue from the children with ALL and control children.

The sixth objective will be met through a collaborative discussion with a variety of local, State, and Federal agencies in an attempt to discern potential causative agents, or mixture of agents, that my define ALL risk in the Fallon, Nevada area.

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PROBLEM

A cluster of Acute Lymphocytic Leukemia (ALL) cases in the Fallon, Nevada (figure 1) area was identified during the summer of 2000. To date, thirteen children have been diagnosed with ALL, and an additional child has been diagnosed with Acute Myolitic Leukemia. One child has died. All victims have lived in the Fallon area for varying lengths of time between 1993 and 2001. The expected rate for ALL is about 3 cases per 100,000 people per year, meaning that one case of ALL would be expected in the Fallon population every five years (Randall Todd, Nevada State Epidemiologist, personal communication).

Dr. Mary Guinan, Nevada State Health Officer, convened an expert panel on February 15, 2001 to consider priorities for the Nevada Health Division in addressing the developing crisis. The panel indicated that the causes of ALL are insufficiently understood to single out specific factors that would explain the observed cluster. Investigations of previous ALL clusters have failed to uncover explanations of the cause of these excess incidences of disease. The expert panel made six recommendations to the State: (1) expand efforts to identify additional Fallon ALL cases using existing epidemiologic databases; (2) categorize the observed ALL cases by clinically relevant disease biomarkers; (3) identify potential excess environmental contaminant exposures unique to the community; (4) collect and bank biological specimens for future scientific investigations; (5) determine the characteristics of population movements into the Fallon area; and (6) maintain the expert panel to review study results (http://health2k.state.nv.us/HealthOfficer/Leukemia/FallonExpReport3-2001.pdf).

The Nevada State Epidemiologist convened a meeting April 17, 2001 of State and Federal agencies to address the third expert panel recommendation. USGS presented an overview of its published work in the Fallon area (http://nevada.usgs.gov/fallon/fallon.htm). Discussion focused on radioisotope work published in Open-File Report 94-31, as radiation has been linked to various forms of leukemia. A front-page article in the Reno Gazette-Journal the next morning (April 18, 2001) focused on the USGS report and led to a request from the Nevada Congressional delegation to the Director of the USGS for an immediate study to quantify potential environmental vectors that might be related to the Fallon ALL cluster.

This work plan is designed to support the third recommendation of the expert panel and is the USGS response to the request from the Nevada Congressional delegation for active USGS participation in resolving the crisis in Fallon. The plan has been developed in consultation with the City of Fallon, Churchill County, the Nevada Health Division, the Nevada Division of Environmental Protection, the Nevada State Epidemiologist, the Centers for Disease Control, the Agency for Toxic Substances and Disease Registry, and the staffs of Senators Harry Reid and John Ensign and Representative Jim Gibbons. The time frame for the study is extremely compressed in order to meet the needs of the State and Federal agencies that require the data on an extremely tight schedule.

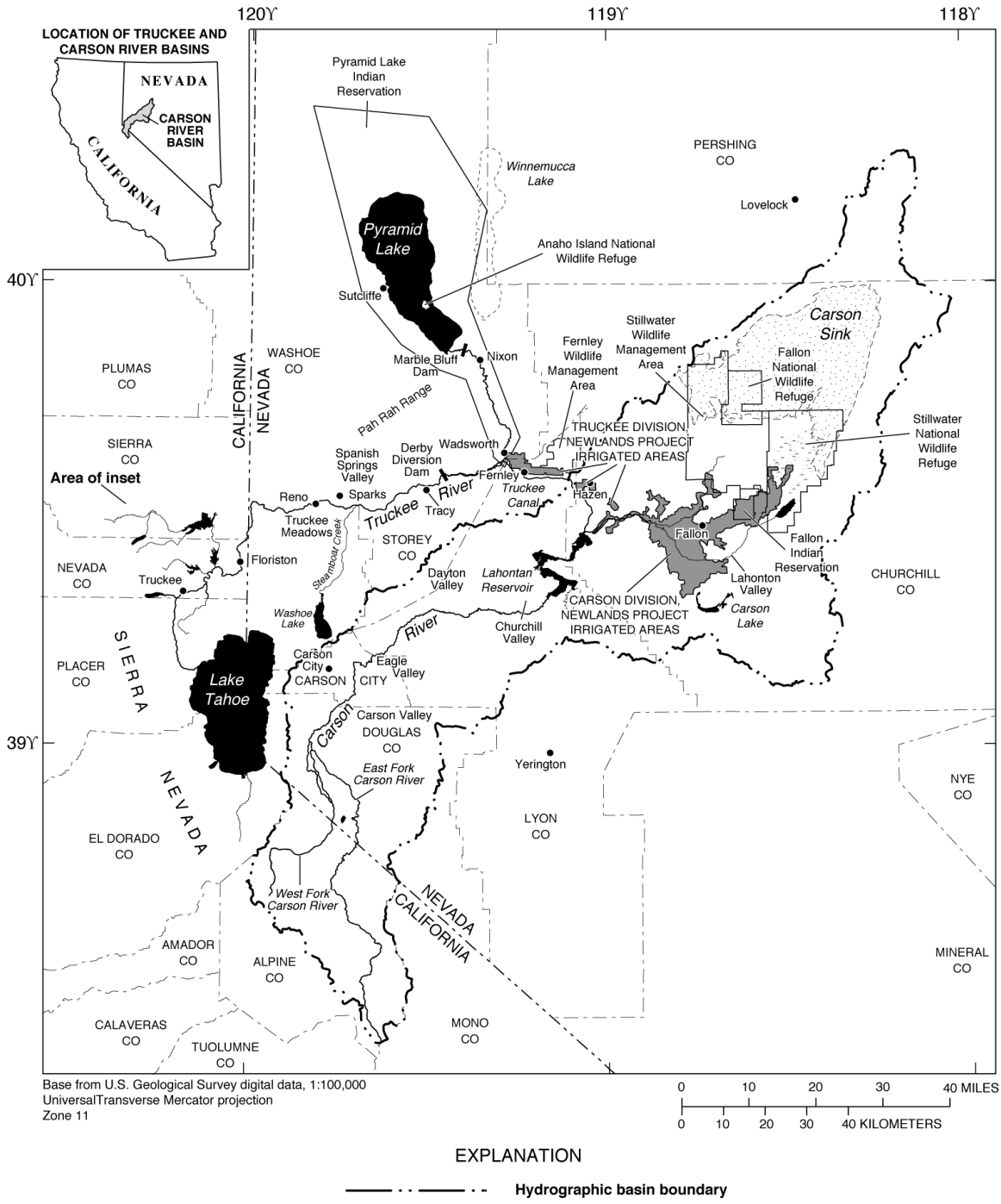

Figure 1: Location Map showing Fallon, NV, relative to the Carson and Truckee River systems.

OBJECTIVES AND SCOPE

This study has six objectives: (1) to characterize current chemical quality of all drinking water sources in the Fallon area; (2) to determine if there have been changes in water quality over the last decade; (3) to evaluate differences in water quality using a variety of statistical techniques; (4) to evaluate if water consumed by the case families differs from water consumed by the community as a whole; (5) to correlate water quality conditions with soil and dust analyses collected by the Nevada Division of Environmental Protection and with bioassay data collected by the Centers for Disease Control; and (6) to relate any identified correlations with the incidence of ALL..

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RELEVANCE AND BENEFITS

The USGS was specifically requested by the Nevada Congressional Delegation to perform this study. Additionally, this study directly supports issues identified in the USGS Water Resources Discipline (WRD) strategic plan, the Strategic Directions for the WRD document, and the Nevada District Science Plan. While not being funded under the USGS Cooperative Water Program, several priority issues of that program are also addressed.

WRD Strategic Plan

Issue 3 specifically addresses drinking water availability and quality. This study will provide a better description of water quality conditions in the Fallon area and will provide empirical data that can be used to optimize monitoring expenditures for drinking water sources. The study will also provide critical data to State health agencies, the Centers for Disease Control, and the Agency for Toxic Substances and Disease Registry in their investigations of the leukemia cluster.

Issue 5 addresses remediation of contaminated environments. Concerns have been raised that the leukemia cluster might be caused by man-made contaminants. The experimental design calls for collecting samples in areas affected by past industrial, mining, military, agricultural, and commercial activities. Data collected also can be used in research efforts related to processes that control the transport and fate of contaminants.

Strategic Directions for the WRD

This study will provide specific information that will advance current knowledge about the hydrologic systems in the Fallon area. It will also provide data that can be used to advance the understanding of hydrologic processes in terminal sinks unique to the Great Basin. The data and information will be used by multiple local, State, and Federal agencies in dealing with the leukemia cluster.

Priority Issues for the Cooperative Water Program

This study is not being funded under the Cooperative Water Program, but does address several of that program's priority issues. Data generated during the study will support local,

State and Federal health agencies in dealing with a major health crisis in the Fallon area. The data also will be useful in determining the effects of land-use practices on ground water.

Nevada District Science Plan

This study directly supports Issue 2, Human Health; Issue 3, Ecological Health; Issue 4, Quality of Life; and Issue 7, Regional Ground-Water Systems.

APPROACH

There are four aquifers in the Fallon area (figure 2). The shallow aquifer extends from the water table, generally less than 3 meters below land surface, to a depth of about 15 meters. The aquifer is characterized by abrupt changes in lithology and water quality, both horizontally and vertically. These abrupt changes are due to constantly changing depositional environments during Pleistocene time that produced a complex mixture of river-channel, delta, flood-plain, shoreline, lake-bed, and sand-dune deposits. Because deltas of the Carson River formed in the western part of the basin, sediments in the shallow aquifer are coarser to the west and become increasingly finer toward the east.

Water level altitudes in the shallow aquifer show that shallow ground water flows northeastward in areas north of Fallon, and southeastward in areas south of Fallon. Detailed studies have shown that directions of ground water-water flow vary greatly over small scales, and are controlled by the presence of canals and drains and by irrigation practices on individual fields (Lico and others, 1987; Lico, 1992). Relict channels of the Carson River also control ground water flow and are important avenues for distribution of recharge to deeper aquifers.

Water level fluctuations show that the shallow aquifer is recharged by surface-water seepage during the irrigation season. Water-level fluctuations closely match the seasonal fluctuations in surface-water flow for irrigation. Vertical gradients are downward during the irrigation season, then reverse during the winter. Water level declines during the winter months are generally limited by the depth of drains, which typically range from 1 to 3 meters below land surface.

The intermediate aquifer has been delimited from the shallow aquifer by an abrupt change from hard ground water in the shallow aquifer to soft ground water in the intermediate aquifer. This water quality change occurs at a depth of about 15 meters. The base of the intermediate aquifer is at the interface of tertiary age deposits underlying the quaternary age deposits at a depth of about 150 to 300 meters below land surface. Deposits comprising the intermediate aquifer range from sandy gravel near the Carson River west of Fallon, to more sandy deposits toward the center of the basin. Near Carson Lake and Stillwater Wildlife Management Area, deposits become more silty and clayey.

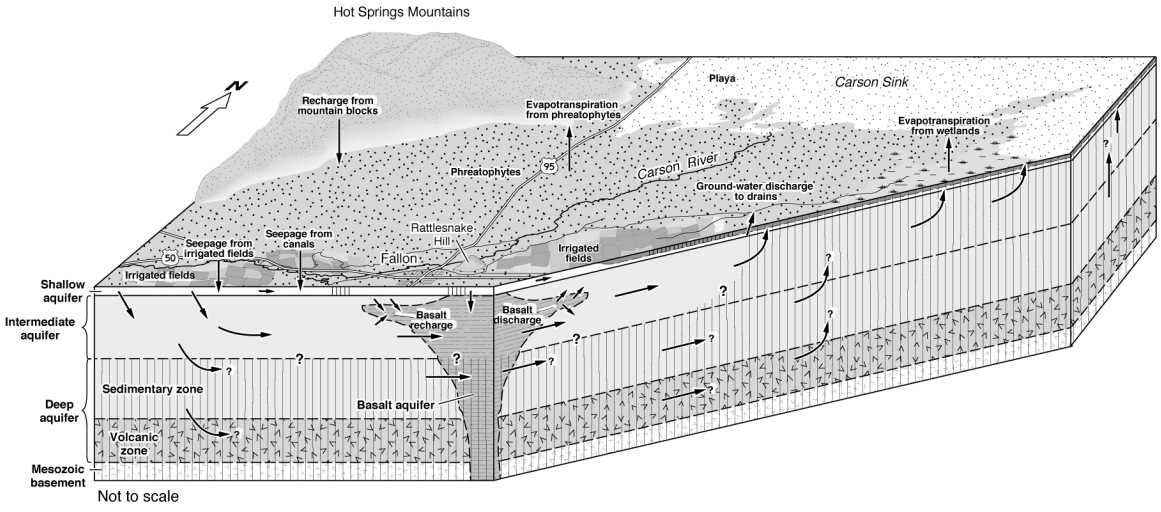
Differences in water-level altitude between the shallow and intermediate aquifer demonstrate a potential for downward ground-water flow in the western part of the basin, and potential for upward flow in the eastern part of the basin. Gradients tend to be relatively flat near the center of the basin. Horizontal flow directions tend to mimic those in the overlying shallow aquifer.

Information about the deep aquifer is limited by the number of deep wells drilled in the basin. The deep aquifer extends from the top of the tertiary-age deposits to the tertiary-age volcanic rock basement of the basin. Few wells utilize water from the deep aquifer because of poor water quality. Dissolved solids concentrations range from 1000-5000 mg/L.

The fourth aquifer is the basalt aquifer. Geophysical data show the lateral extent of the basalt is greatest about 200 meters below land surface, and that between 300 and 1200 meters the basalt decreases in lateral extent to a vertical volcanic neck about 1.6 km in diameter. Basalt forming the aquifer ranges from dense, fractured lava flows, to basalt rubble and cinders between the flows.

Water levels in the basalt aquifer indicate a nearly flat potentiometric surface with a small gradient to the northeast. Water-level fluctuations show annual declines caused by pumpage during the summer, followed by recovery during the winter. Long term, water levels in the basalt aquifer have been declining. The continued decline of water levels in the basalt aquifer, combined with long-term stability of water levels in the shallow and intermediate aquifers, have increased the potential for recharge from the shallow and intermediate aquifers to the basalt aquifer.

Of the four aquifers in the Fallon area, only three are used for drinking water supply. The City of Fallon, the Fallon Naval Air Station, and the Fallon Paiute-Shoshone Tribe draw their public supplies from the basalt aquifer. Public supply wells typically are around 200 meters deep. Most rural wells draw their water either from the shallow aquifer, the intermediate aquifer, or a combination of the two.



Conceptualized ground–water flow paths and sources of inflow to and outflow from aquifers in Carson Desert

Figure 2: Cartoon showing the Fallon area aquifer systems.

Task 1 addresses the first objective of this study. A sufficient number of ground water samples from each of the utilized aquifers will be collected to adequately define current water quality conditions. The total number of samples to be collected is 100. A four-level stratified sampling design has been developed. The first level will be to duplicate sites included in USGS Open-File Report 94-31 (see Figure 3). The second level will focus on collecting additional water quality data in areas where residential development has occurred since that report was published. The third level will provide site-specific data in the areas near where leukemia cluster families have lived, including wells servicing their residences, subject to well owner permission. The fourth level will focus in the area of a jet fuel pipeline that many Fallon residents suspect as a focus of contaminants in the drinking water supply. All public supply wells will be sampled.

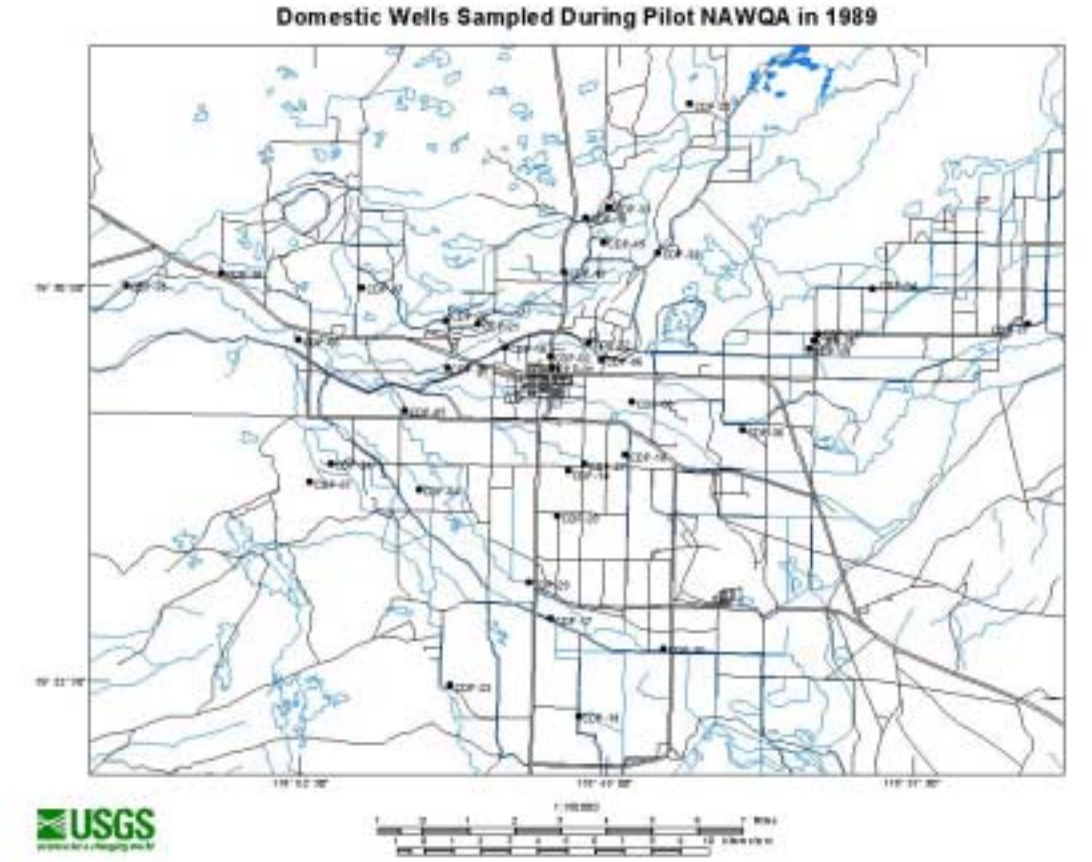


Figure 3: Domestic wells sampled during the Pilot National Water Quality Assessment study published in USGS Open-File Report 94-31.

Samples will be collected using NAWQA sampling and quality assurance/quality control (QA/QC) procedures. Specifics of the procedures are given in Koterba and others, 1995. The USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, will analyze the samples. The analysis suite includes at least 266 different chemicals, including: major anions and cations (salts); metals such as mercury, arsenic and selenium; chemical form for several metals; volatile organic compounds; pesticides; radioactive materials; and consumer chemicals. Analytical schedules that will be used are given in Table 1. NWQL QA/QC procedures can be found at:

http://wwwnwql.cr.usgs.gov/Public/pubs/QC_Fact/text.html

Table 1. Analytical Schedules

Analyte Suite	**Schedule**
NAWQA Major Inorganics	Schedule 2750
NAWQA ICP-MS 22 Element	Schedule 2710
Trace Metals in Unfiltered Water	Schedule 1658
NAWQA Nutrients	Schedule 2752
Pesticides	Schedule 2001
Polar Pesticides	Schedule 2060
NAWQA VOC's	Schedule 2020
Semivolatile Organic Compounds	Schedule 1383
Uranium Isotopes	Schedule 1635
Alkalinity	Lab Code 2109
Mercury	Lab Code 2708
Stable Isotopes	Schedule 1142
Radon	Schedule 1369

The Centers for Disease Control and the Agency for Toxic Substances and Disease Registry will be collecting biologic samples from the leukemia victims and control children during August 2001. USGS will be collaborating with them in correlating tissue results with water quality results. This collaboration requires a highly compressed sampling and analysis schedule. To accommodate this compressed schedule, the sampling phase of the water quality study should be completed by the end of July. Chemical analyses should be completed by early October.

Task 2 addresses the second study objective. Data defining current conditions will be compared to data defining conditions previously published in several USGS and State agency reports. Maps will be produced showing concentration contours for key chemical constituents and showing areas where significant concentration changes have occurred. If sufficient historical data exists, water quality trends will be evaluated.

Task 3 addresses the third study objective. Principal component and cluster analytical tools will be used to analyze the data. Precise tools that will be used for this and subsequent tasks will be selected in consultation with appropriate USGS Regional, Headquarters, and National Research Program staff, as well as staffs of State and Federal agencies. Where appropriate, Stiff diagrams will be constructed to visually highlight ground water differences in the various aquifers. Where data exists, ground water will be age-dated.

Task 4 addresses the fourth study objective. Differences between water quality at case family residences will be compared to water quality for non-case family residences in the same areas using the results of Task 3.

Task 5 addresses the fifth study objective. Data collected by USGS and data collected by other participating agencies doing complementary media analyses will be integrated. At present, the Nevada Division of Environmental Protection plans to collect and analyze soil and dust

samples at case family residences and at control family residences. Similarly, the Centers for Disease Control is planning on sampling blood, urine, and tissue from the children with ALL and control children.

Task 6 addresses the sixth study objective. Through collaborative discussions with a variety of local, State, and Federal agencies, discernable potential causative agents, or mixture of agents, that my define ALL risk in the Fallon, Nevada area will be explored.

Specific statistical and quantitative tools that will be used in meeting objectives three through six will be determined in consultation with the appropriate regional and headquarters specialists.

REPORTS

Data from this study will be made available using existing USGS water quality databases and will be linked to our Fallon web page as soon as QA/QC procedures allow. Periodic press releases will be prepared as data becomes available. An Open-File report presenting the data collected will be prepared early in Fiscal Year 2002 (FY02). A Professional Paper that describes detailed analysis of the data will be published by the end of FY02. In addition, several journal articles are anticipated, as are collaborative publications produced by the other agencies doing studies related to the ALL cluster.

PERSONNEL

The compressed sampling schedule for Task 1 will require use of multiple crews. Approximately 25 District staff will be involved, helping for various periods of time during June and July 2001. This phase of the project will be managed by a troika: Ralph Seiler will serve as Project Chief coordinating field activities, Sharon Watkins will coordinate supply and staff logistics, and Terry Rees will coordinate project planning, fiscal planning, external agency coordination and press/outreach activities. Tasks 2-6 will principally involve the troika, but may also require the assistance of a student.

BUDGET

Total funding for this project is estimated at $ 1,125,500. Activities in FY01 will require $ 503,000 net-to-District funds, while activities in FY02 will require $ 622,500 gross funds. Funding for each task is estimated to be:

Task 1: This task will be completed during FY01. Funds needed for Task 1 is estimated at $503,000 net-to-District. Funding will be provided entirely by USGS.

Labor	$ 70,000
Travel	$ 10,000
Supplies	$ 10,000
Equipment	$ 3,000
Vehicles	$ 5,000
Postage/Freight	$ 1,000
NWQL Charges	$ 362,000
Lab Supplies	$ 42,000
TOTAL	**$ 503,000**

Task 2: This task will be completed during FY02. Estimated funding needed is $ 105,500. .Potential sources of funding include internal USGS monies, Congressional appropriation specifically for this project, State of Nevada Division of Health Services (perhaps through the cooperative water program), and the Centers for Disease Control. Funding for this and all subsequent tasks will be fully assessed.

Labor	$ 70,000
Travel	$ 2,000
Supplies	$ 3,000
Equipment	$ 5,000
Vehicles	$ 500
Postage/Freight	$ 0
Reports	$ 25,000
TOTAL	**$ 105,500**

Task 3: This task will be completed during FY02. Estimated funding needed is: $ 114,500. Potential sources of funding include internal USGS monies, Congressional appropriation specifically for this project, State of Nevada Division of Health Services (perhaps through the cooperative water program), and the Centers for Disease Control. Funding for this task will be fully assessed.

Labor	$ 70,000
Travel	$ 4,000
Supplies	$ 10,000
Equipment	$ 5,000
Vehicles	$ 500
Postage/Freight	$ 0
Reports	$ 25,000
TOTAL	**$ 114,500**

Task 4: This task will be completed during FY02. Estimated funding needed is: $ 78,500. Potential sources of funding include internal USGS monies, Congressional appropriation specifically for this project, State of Nevada Division of Health Services (perhaps through the cooperative water program), and the Centers for Disease Control. Funding for this task will be fully assessed.

Labor	$ 50,000
Travel	$ 2,000
Supplies	$ 1,000
Equipment	$ 0
Vehicles	$ 500
Postage/Freight	$ 0
Reports	$ 25,000
TOTAL	**$ 78,500**

Task 5: This task will be completed during FY02. Estimated funding needed is: $ 162,000. Potential sources of funding include internal USGS monies, Congressional appropriation specifically for this project, State of Nevada Division of Health Services (perhaps through the cooperative water program), and the Centers for Disease Control. Funding for this task will be fully assessed.

Labor	$ 100,000
Travel	$ 10,000
Supplies	$ 1,000
Equipment	$ 1,000
Postage/Freight	$ 0
Reports	$ 50,000
TOTAL	**$ 162,000**

Task 6: This task will be completed during FY02. Estimated funding needed is: $ 162,000. Potential sources of funding include internal USGS monies, Congressional appropriation specifically for this project, State of Nevada Division of Health Services (perhaps through the cooperative water program), and the Centers for Disease Control. Funding for this and all subsequent tasks will be fully assessed.

Labor	$ 100,000
Travel	$ 10,000
Supplies	$ 1,000
Equipment	$ 1,000
Postage/Freight	$ 0
Reports	$ 50,000
TOTAL	**$ 162,000**