THE CHURCH ROCK URANIUM MILL TAILINGS SPILL: A HEALTH AND ENVIRONMENTAL ASSESSMENT

SUMMARY REPORT

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Executive Summary

The largest single release of liquid radioactive waste in the United States occurred at the United Nuclear Corporation's uranium mill near Church Rock, New Mexico, in July 1979. This document reports the results of environmental monitoring conducted by the New Mexico Environmental Improvement Division (EID) subsequent to the mill tailings spill. Interpretation of data leads to the general conclusion that although the spill was potentially hazardous, its short-term and long-term impacts on people and the environment were quite limited. However, the data suggest that dewatering effluents (water from underground uranium mines) continually pumped into the Puerco River may represent a greater long-term hazard than the spill. Recommendations are made regarding continued environmental monitoring and resumption of normal land and water use along the Puerco River. EID is also issuing two technical reports to provide more detailed information on the spill and its impacts.

The spill occurred early on the morning of July 16 when the retention dam for a tailings pond failed. Most of the 1100 tons of solid material released was caught by a small emergency catchment dam. However, most of the 94 million gallons of liquid entered the Puerco River. The acidic, saline, and radioactive waste flowed down the Puerco River channel through Gallup, New Mexico, and into Arizona, where evaporation and seepage into the stream bed caused flow to cease. The spill prompted environmental monitoring efforts by several governmental agencies. EID, which began monitoring uranium industry impacts in 1974, expanded and intensified its data collection programs for surface water, ground water and air. In addition, arroyo sediments, vegetation, livestock and some local residents were tested for spill effects by EID or by other agencies.

Interpretation of EID sampling results and evaluation of conclusions presented by other organizations leads to the following conclusions and recommendations.

1. The U.S. Centers for Disease Control (CDC), in cooperation with the Church Rock community, found no documented human consumption of river water. Six Navajo individuals most likely exposed to spill contaminants were selected by the CDC and tested at Los Alamos National Laboratory, where they were found to have amounts of radioactive material normally found in the human body.

   Recommendation: No further action required.

2. Spill impacts on surface water quality are no longer evident. Present surface water quality closely resembles prespill conditions and is determined primarily by dewatering effluents and natural runoff. These waters contain levels of radioactivity and certain toxic metals that approach or exceed standards and guidelines designed to protect the health of people, livestock and agricultural

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crops. Regardless of the source of contaminants, Puerco River water may be hazardous if used over several years as the primary source of drinking water, livestock water or irrigation water. The severity of these hazards is not well known at this time.

Recommendations: The Puerco River should not be used as a primary source of water for human consumption, livestock watering or irrigation.

Additional study of dewatering effluents and natural runoff is needed to better define potential hazards associated with prolonged use of these waters.

3. Testing of livestock for radioactivity and toxic metals was sufficient to permit only preliminary conclusions. Sheep, goats and cattle sampled along the Puerco River had higher concentrations of radioactivity in bone, liver and kidney compared to control animals. The CDC observed that because older animals seem to have higher levels, the probable sources of the contaminants were dewatering effluents and natural runoff, rather than the spill.

Recommendations: Based on limited testing conducted by the CDC, the additional radiation risk from consumption of local livestock is small. The risk is about the same as the increased risk from cosmic radiation incurred by moving from sea level to 5000 feet in elevation. For persons wishing to minimize this small additional risk, consumption of liver and kidney should be avoided.

To minimize uncertainty generated by the preliminary results, Church Rock area livestock should be further sampled to determine concentrations of radioactivity and toxic metals in edible tissues and to re-evaluate long-term risks associated with consumption of such tissues.

4. No public, private or municipal wells producing water for domestic use or livestock watering were affected by the spill. Wells drawing water solely from sandstone or limestone aquifers probably will never be affected by spill contaminants. However, some EID test wells drawing water from the shallow valley sediments produce water with elevated levels of salinity and radioactivity due to the spill. While ground water moves slowly and contamination is slight and confined to limited areas, other shallow wells may become influenced by the spill in the future.

Recommendations: Public or private wells drawing water from the alluvium should be tested annually by appropriate authorities for salinity and gross alpha radioactivity. Existing drinking water testing programs conducted under the federal Safe Drinking Water Act are adequate.

New wells drilled in the Puerco River valley should be designed to draw water from sandstone or limestone aquifers. If an alluvial well is necessary, the upper 100 feet of alluvium should be sealed off.

5. The hazard associated with inhalation of contaminated river sediments suspended in the air as dust is negligible for local residents. Computer modeling identified inhalation as the most significant pathway of radiation exposure to man from the spill. However, sampling of airborne dust along the Puerco River in Gallup soon after the spill showed only background levels of radioactivity. Moreover, one year following the spill, radioactivity levels in Puerco River sediments were reduced significantly due to dilution with uncontaminated river sediments. Therefore, avoiding the arroyo during windy conditions is considered to be of minor importance and not necessary for the protection of public health.

   Recommendation: No further action required.

6. Native grasses, shrubs and corn samples collected along the Puerco River contained concentrations of radioactivity that fell within the range of background values. No spill effects were evident.

   Recommendation: No further action required.

7. Neither an aerial nor a ground survey of the Puerco River area detected any external penetrating (gamma) radiation levels attributable to the spill.

   Recommendation: No further action required.

To summarize, the spill affected the Puerco River valley environment for a brief period, and had little or no effect on the health of local residents. Of greater concern today are the quality of perennial dewatering effluents in the Puerco River and the quality of natural runoff following thunderstorms or snowmelt. These waters, although not consumed by people, are available to local livestock and have influenced the quality of shallow ground waters in some places. The extent to which radioactive and chemical constituents of these waters are incorporated in livestock tissue and passed on to humans is unknown and requires critical evaluation. EID has obtained funding to study this issue. An additional concern is the potential for residual spill contaminants and dewatering effluents to further degrade shallow ground waters. An ongoing EID study, scheduled for completion in 1983, addresses the effects of dewatering effluents and possible control measures.

Requests for copies of this and other EID reports on the Church Rock spill should be addressed to the Director of the EID, P.O. Box 968, Santa Fe, New Mexico, 87504-0968.

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1.0 INTRODUCTION

1.1 Background Information

Early on the morning of July 16, 1979, at the United Nuclear Corporation (UNC) Church Rock uranium mill, the dam for the south tailings pond failed (Figure 1.1). The pond held liquid and solid mill waste. Approximately 94 million gallons of mill waste fluids and 1100 tons of tailings solids were released. This was the largest single release of liquid radioactive waste recorded in the United States and the fifth largest release of solid radioactive waste. Most of the solids were caught by a small emergency catchment dam, but the bulk of the liquid entered Pipeline Arroyo, a tributary of the Puerco River.*

The spill materials flowed down the Puerco River channel through the City of Gallup, New Mexico (Figure 1.2). Downstream travel of the waste was enhanced by the flow of 5000 gallons per minute of water continuously pumped into Pipeline Arroyo by routine dewatering operations at upstream uranium mines. Gradual losses to evaporation and infiltration caused flow to cease near Chambers, Arizona, about 60 air miles and 100 river miles downstream from the UNC mill.

Released tailings liquid contained a number of radioactive and chemical constituents that posed potential threats to public health and the environment. Of particular concern were 1) radionuclides present in uranium ore (Figure 1.3), primarily uranium-238, thorium-230, radium-226, lead-210 and polonium-210, 2) toxic metals including elemental lead, molybdenum, arsenic and selenium, 3) acidity and 4) high levels of dissolved salts, particularly sulfate.

Aside from direct contact, the tailings spill could affect public health through the following mechanisms:

1. Water-borne contaminants in the Puerco River may infiltrate into the ground and impair the quality of shallow ground water. Because ground water moves slowly, such degradation could remain undetected until a private well is affected.

2. Livestock could ingest contaminated sediments by drinking water from the Puerco River. Over a long period of time, this may result in hazardous accumulations of radionuclides or metals in animal tissues. These tissues could then be consumed by people.

3. Contaminated sediments from the Puerco River may be suspended as dust and inhaled by local residents or deposited on vegetation and consumed by livestock.

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* The Puerco River originates at the continental divide and flows westward through Gallup, eventually joining the Colorado River system in Arizona. It should not be confused with the Rio Puerco which originates near Cuba, New Mexico and joins the Rio Grande.

Figure 1.2. Map of the Puerco River Region.

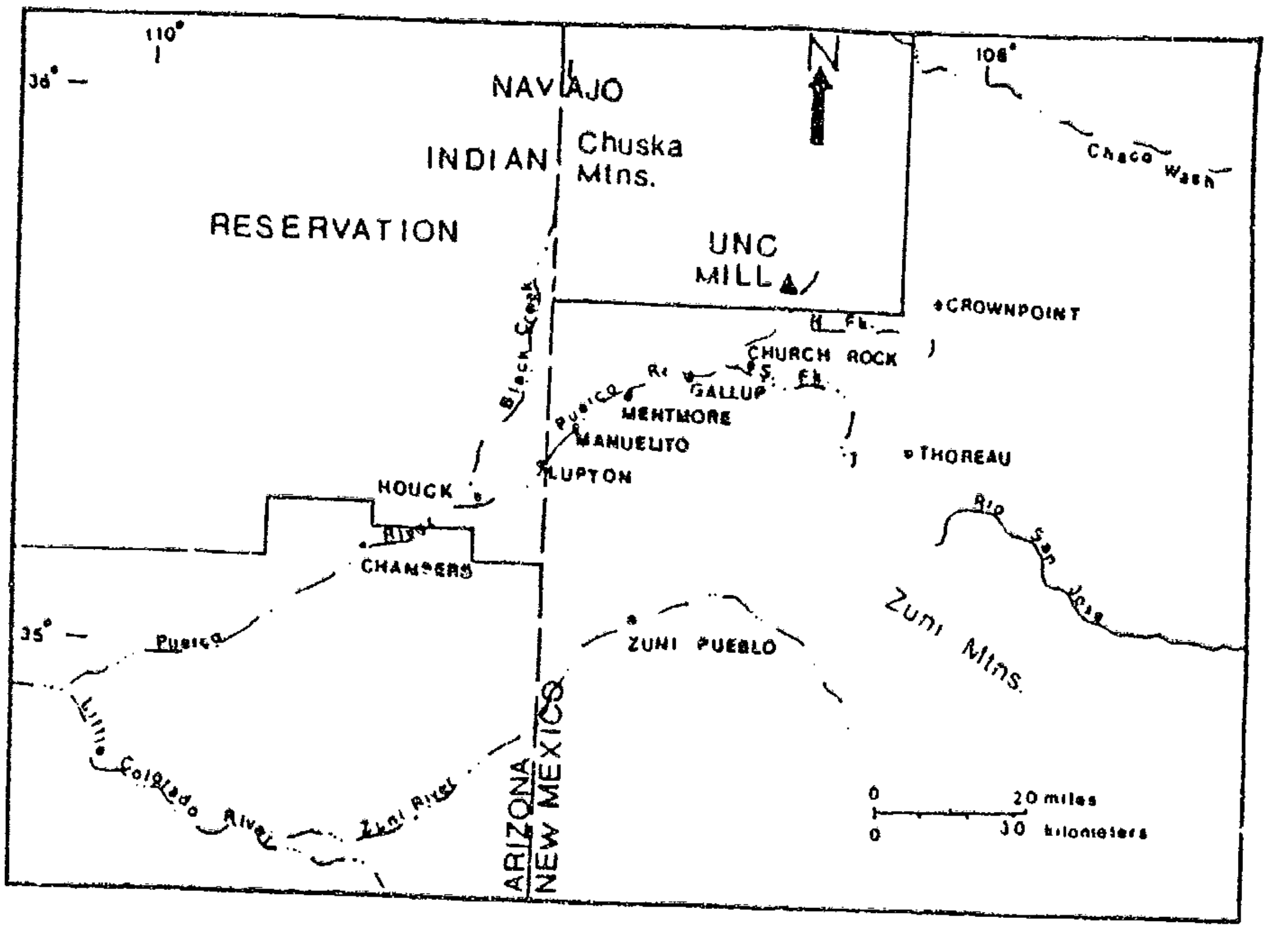

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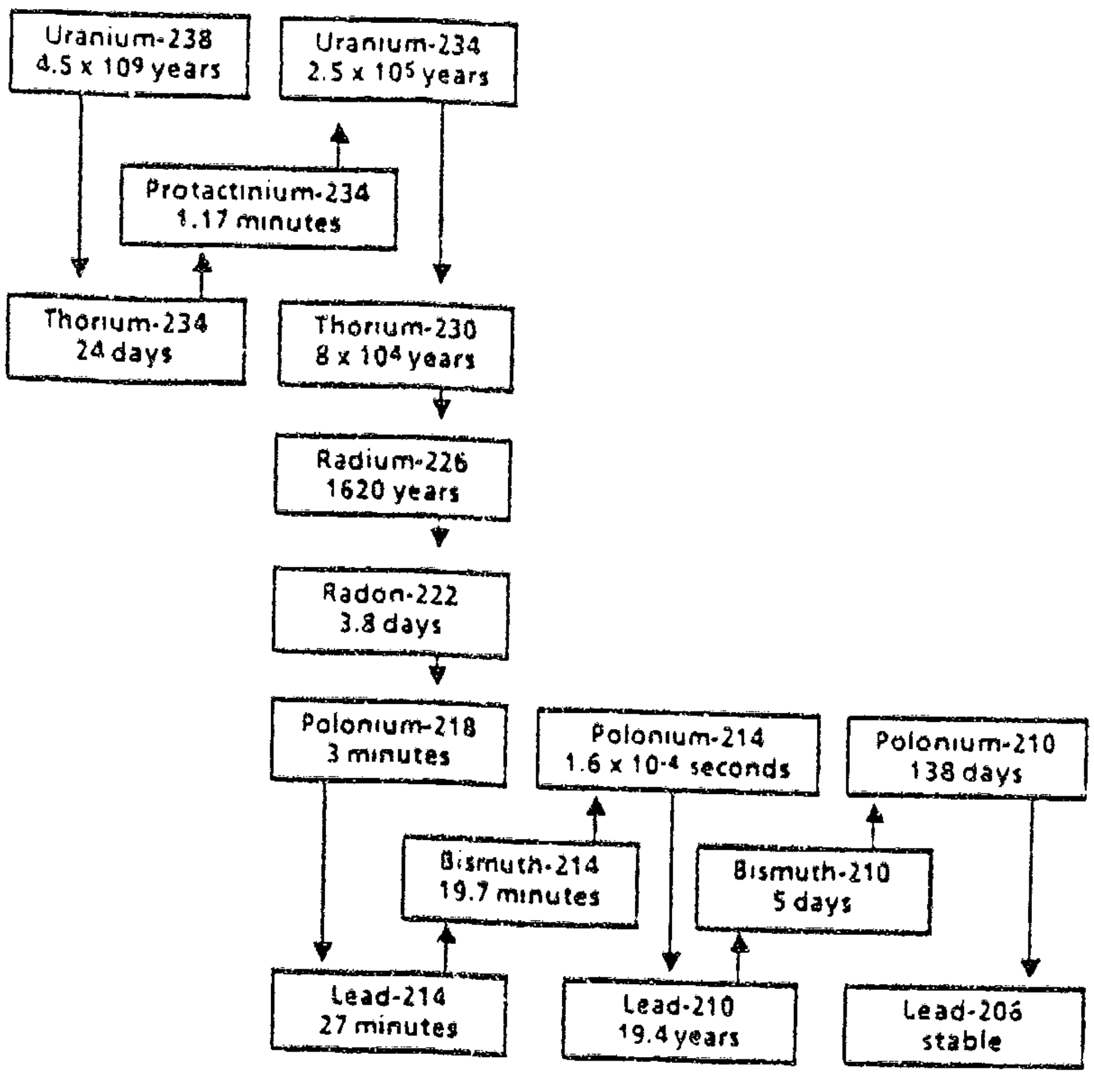
Figure 1.3. Principal radionuclides in the uranium-238 decay chain. The half-life of each nuclide is shown. Downward pointing arrows indicate alpha emissions and upward pointing arrows indicate beta and/or gamma emissions.



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1.2 Environmental Monitoring and Regulatory Response

Because of the amount of tailings released, the toxicity of the waste and the size of the area affected, the reaction of public agencies to the spill was rapid. Within a few hours of the dam failure the New Mexico Environmental Improvement Division (EID) initiated stream monitoring and ordered UNC to cease the discharge of tailings to the breached pond. To comply with this order, UNC ceased milling operations and remained shut down for about three months. Two days after the spill (July 18, 1979) EID further ordered that UNC act to contain spill effluents and to collect contaminated materials. Clean-up standards and procedures for this undertaking were provided by EID. In addition, UNC complied with the EID request to post warning signs along the Puerco River discouraging use of the water.

In order to assess the immediate and long-term environmental effects of the spill, several government agencies and private firms became involved with sampling and monitoring programs. Government agencies included:

1. New Mexico Environmental Improvement Division
2. New Mexico Scientific Laboratory Division
3. U.S. Centers for Disease Control
4. U.S. Nuclear Regulatory Commission
5. Los Alamos National Laboratory
6. U.S. Public Health Service, Navajo Area Indian Health Service
7. U.S. Environmental Protection Agency
8. U.S. Department of Energy, Idaho Radiological and Environmental Sciences Laboratory
9. Arizona Department of Health Services

Private contractors and cooperators included:

1. United Nuclear Corporation
2. Battelle Pacific Northwest Laboratory
3. Eberline Instrument Corporation
4. EG&G, Inc.

The overall effect of cooperation between these groups was a broad environmental monitoring effort that examined stream sediments, surface water, ground water, drinking water, air, livestock, vegetation and people. EID issued three status reports following the spill (1, 2, 3). Several organizations have already published final reports on their monitoring efforts (4, 5, 6, 7, 8). Independent reviews of Puerco River monitoring programs have been performed as well (9, 10).

1.3 Geographic Setting

Physical Characteristics

The Puerco River, at an altitude of 6000-7000 feet, drains the southern Colorado Plateau in New Mexico and Arizona. Here sedimentary rocks have been tilted and eroded, creating a landscape of alternating mesas and broad alluvial valleys (Figure 1.4). Upland areas are capped by erosion-resistant strata such as sandstone; river valleys have been excavated from less resistant formations such as shale. Major mountain ranges in the area are the Zuni Mountains, which border the Puerco River watershed on the southeast, and the Chuska Mountains, which bound the river basin on the north.

A temperate, semi-arid climate is characteristic of the region's broad valleys. At Gallup annual precipitation usually ranges between 10 and 15 inches. An excess of evaporation over precipitation causes a water deficit that is most pronounced during the summer months.

In the uplands, the dominant vegetation is woodland interspersed with grassland. In contrast, lowland areas can only support a sparse ground cover of grasses and drought-resistant shrubs (Figure 1.4). Stream-side vegetation is largely absent from the Puerco River valley.

Except for a few isolated springs and mountain streams, the Puerco River watershed has no naturally perennial surface waters. U.S. Geological Survey records from the 1940s document that prior to uranium mine dewatering the Puerco River was dry more than 70 percent of the time, flowing only during spring snowmelt and major summer thunderstorms. Since 1968, dewatering of underground uranium mines has caused perennial flow in the Puerco River. Perennial conditions now exist from above Church Rock to several miles beyond the Arizona border.

Water from the Puerco River replenishes the shallow ground water contained in river valley sediments. Characteristics of this aquifer vary widely from place to place. The sediments consist of sands, silts and clays derived from sandstones and shales. Often these materials are relatively impermeable and do not yield water easily (less than 5 gallons per minute). However, occasional sand deposits are permeable and wells tapping such zones can be moderately productive (up to 200 gallons per minute). The few shallow alluvial wells in the valley are used chiefly to provide water for livestock.

Water for human consumption comes mostly from sandstone aquifers more than 400 feet below the land surface. These aquifers are replenished primarily by precipitation in areas where the rock is exposed at the land surface. Quality of water from these aquifers near Gallup is generally superior to that from the alluvial aquifer.

Cultural Features

Most of the region is sparsely populated by pastoral Navajo families. The major concentration of people in the region is the City of Gallup (pop. = 20,000). Smaller communities of less than 1000 inhabitants also occur along the Puerco River: Manuelito, Mentmore and Church Rock in New Mexico, and Lupton and Chambers in Arizona. These few villages do not alter the overwhelmingly rural nature of the Puerco River watershed.

The two major land uses in the area are agriculture and mining. Most rural inhabitants graze sheep, goats, cattle and horses over large areas (Figure 1.5). Irrigation is not practiced commercially, although rural families probably irrigate private vegetable plots. Less widespread are coal mining, south and west of Gallup, and uranium mining and milling, north of Church Rock.

The Puerco River valley has a complex pattern of land ownership. Large blocks of land in the northern portion of the basin are either on the Navajo Reservation or part of the Navajo Trust lands. The U.S. government, through the Bureau of Land Management, also administers large tracts of land. Overall, the ownership pattern can best be described as a "checkerboard" with portions owned or leased by the Navajos, private individuals, the U.S. government and the State of New Mexico.

2.0 SAMPLE COLLECTION AND ANALYSIS

2.1 Surface Water

Prior to the spill, surface water samples were collected four times per year at two locations on the Puerco River (Figure 2.1) as part of an ongoing regional water quality study (11). Samples were collected more intensively during and after the spill. Most surface water samples were filtered to remove suspended material and then acidified to preserve dissolved concentrations of metals and radionuclides. However, in order to quantify total contaminant levels, some samples were not filtered.

Water samples were collected and preserved in plastic containers and analyzed by the New Mexico Scientific Laboratory Division for suspended solids, general chemistry, metals, uranium, radium-226 and gross alpha and beta radioactivity (Table 2.1). Eberline Instrument Corporation tested samples for uranium, lead-210, polonium-210, radium-226, radioactive isotopes of thorium and gross alpha radioactivity. Analytical techniques used by these laboratories are listed elsewhere (12, 13).

2.2 Ground Water

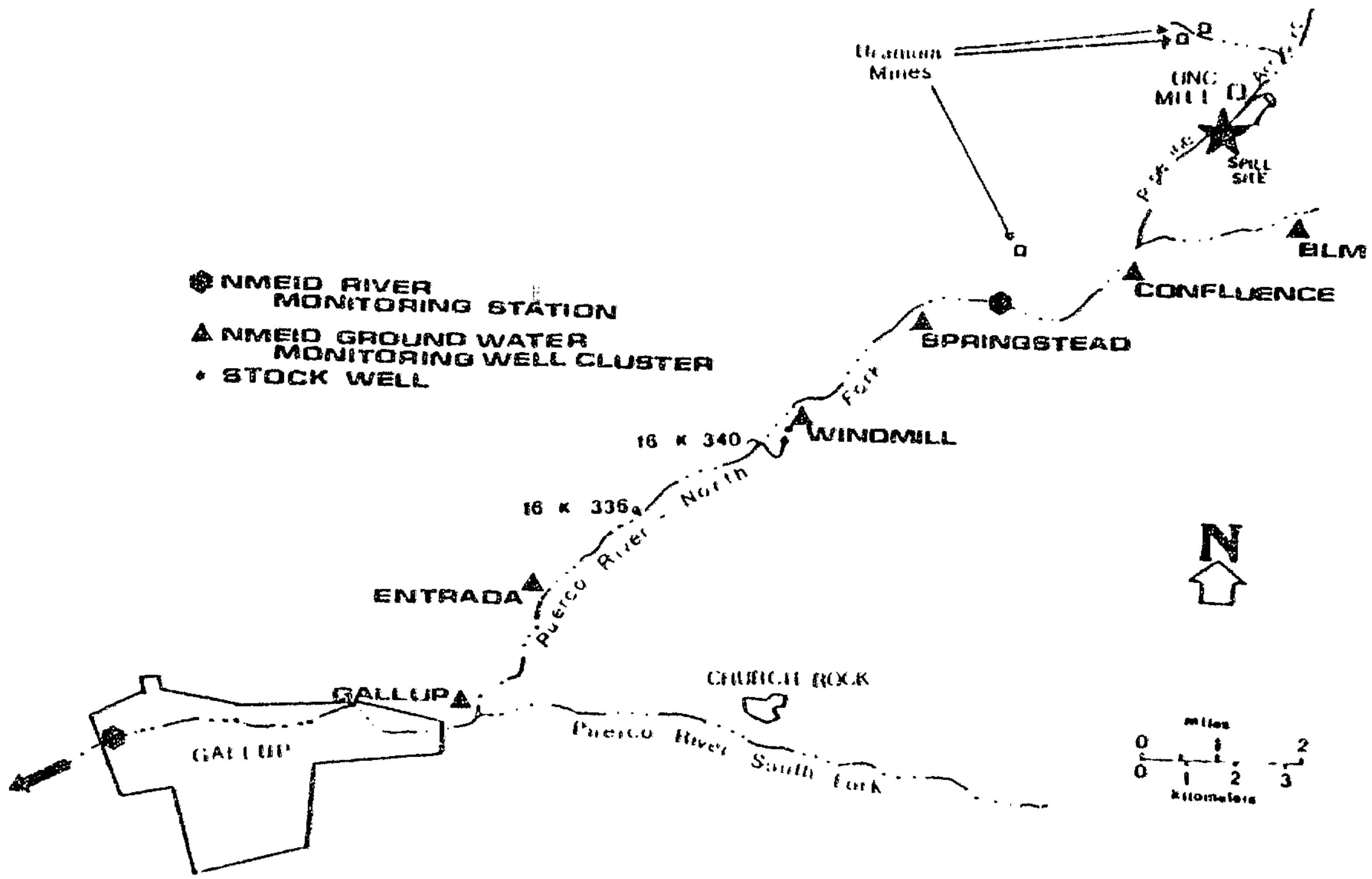
As part of EID's original Grants Mineral Belt study (11), one cluster of four ground water test wells was installed near the Puerco River just east of Gallup in late 1977 (Figure 2.1). These wells, therefore, were in place when the UNC spill occurred. In the summer of 1981, 18 additional monitoring wells were installed in five clusters distributed along the Puerco River. One of these clusters was located above the confluence with Pipeline Arroyo to provide background water quality information. Each cluster has wells at different depths in a spatial design that allows for three-dimensional examination of contaminant distribution in the alluvial aquifer (Figure 2.2).

Ground water samples from test wells were collected quarterly before the spill, monthly for about one year after the spill and quarterly thereafter. Eight private and municipal wells were sampled periodically after the spill. Samples were filtered, preserved when appropriate with acid within 24 hours after collection and transported to the appropriate laboratory for analysis (Table 2.1).

2.3 Soil and Sediment

Collection of soil and stream sediments along the Puerco River was undertaken on several separate occasions by EID. During the major sampling effort in September and October 1979, EID personnel supervised UNC employees in the collection of about 1400 samples (Table 2.1). Surface sediment samples were taken every 1000 feet from the UNC mill to the Arizona border; three-foot cores and background soil samples were taken every 5000 feet (Figure 2.3). Suspected areas of

Figure 2.1. Principal Water Monitoring Sites Along the Puerco River.



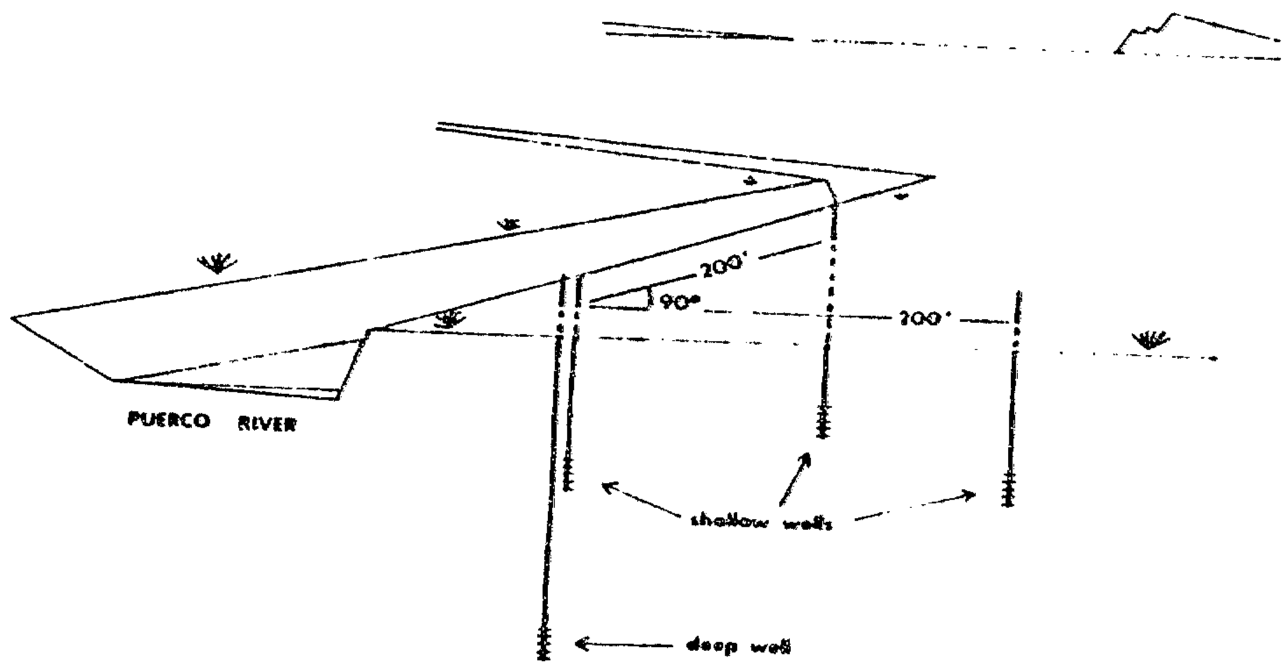


Figure 2.2. Schematic diagram showing three dimensional design of EID well clusters. Shallow wells are about 35' deep; deep wells are about 70' deep. Absolute spacing and arrangement of wells varies; numbers given in diagram are for clarity only.

contamination, such as tributary arroyos, stranded pools, depressions and areas of salt precipitates left by the spill were also sampled. Additional surface sediment samples were collected in Arizona up to the point where flows from the spill ceased.

Radionuclide analyses of soil and sediment samples were performed primarily by a mobile field laboratory owned by Battelle Pacific Northwest Laboratory and made available on site through a contract with the U.S. Nuclear Regulatory Commission. Analyses were also performed by the U.S. Environmental Protection Agency's Las Vegas, Nevada, Laboratory, the U.S. Department of Energy's Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho and Eberline Instrument Corporation in Albuquerque, New Mexico.

2.4 Air Particulates

Two types of airborne particulate samples were collected near the Puerco River by EID (Table 2.1). A continuous air sampler collected dust for 12 weeks between August 1979 and January 1980 to evaluate exposure to the general population in Gallup. A seven-hour sample was collected near a UNC clean-up crew working along the Puerco River to assess occupational exposure. A cascade impactor was used at the clean-up site to determine the amount of inhalable dust.

Filters from airborne particulate samplers were submitted first to the New Mexico Scientific Laboratory Division in Albuquerque, where they were analyzed for elemental uranium and radium-226. Analyses for thorium-230 and lead-210 were then conducted at Eberline Instrument Corporation.

In addition to radioactive particulate monitoring, sampling of radon gas was performed at several locations near the Puerco River. These stations were part of EID's ongoing radon study in the Grants Mineral Belt (14).

2.5 Vegetation and Produce

EID and UNC separately sampled vegetation at ten downstream locations along the Puerco River. Representative forage samples of native grasses and shrubs were obtained at each location. Corn samples were also obtained by EID from three individual residences in close proximity to the Puerco River. Samples were tested for radionuclides (Table 2.1).

2.6 Gamma Radiation

Two extensive surveys were conducted shortly after the spill for gamma radiation (Table 2.1). Using a sensitive sodium iodide detector, an aerial radiological survey was performed by EG&G, Inc., under contract with the U.S. Department of Energy (15). A separate ground survey was conducted by Eberline Instrument Corporation, under contract with UNC, using portable radiation detection equipment (16).

2.7 Livestock Tissue

A possible pathway for radionuclide exposure to man is through eating contaminated meat. For this reason, two cows, four sheep and two goats were obtained from the Church Rock area for testing by the U.S. Centers for Disease Control. These animals were likely to have received both acute exposure from the spill and chronic exposure from mine dewatering effluents. Also, one cow and two sheep not exposed to Puerco River water were sampled as control animals.

2.8 UDAD Computer Code

The Uranium Dispersion and Dosimetry (UDAD) computer code developed by Argonne National Laboratory was used to estimate radiation doses to man from all potential exposure pathways (17). Parameters such as radionuclide concentration in sediment and wind speed and direction are inputted to the code. The code then calculates radionuclide concentrations in dust and, from that, dose to humans. Other pathways, such as radiation in water and direct gamma radiation, are also considered.

Table 2.1 Samples Collected and Analyses Performed.

Sample Description	Number of Samples	Collection Date	Type of Analysis*
<u>Ground water</u>: 8 private and municipal wells, 22 EID test wells sampled.	150	April 1978 to present	15 general water chemistry parameters, 10 metals, gross alpha radioactivity, uranium, Ra-226.
<u>Surface water</u>: Samples collected at several sites from above UNC impoundment downstream to Arizona border.	200	April 1978 to present	15 general water chemistry parameters, 10 metals, gross alpha radioactivity, uranium, Th-230, Ra-226, Pb-210, Po-210.
<u>Surface sediment</u>: Initial survey of 40 samples and main survey of 1400 samples every 1000 feet, including hot spots, pools, salts, terraces, and back-ground sites.	1440	July 19-Oct. 5, 1979	Uranium, Th-230, Ra-226, Pb-210, Po-210.
Major resampling of main channel, side arroyos, and hot spots.	1550	Nov. to Dec. 1980	U-238, Th-230, Ra-226, Pb-210.
<u>Sediment cores</u>: Three-foot cores collected near stream and arroyo bank every 5000 feet.	100	July 31 to Oct. 5, 1979	U-238, Th-230, Ra-226, Pb-210.

Table 2.1 (cont'd)

Sample Description	Number of Samples	Collection Date	Type of Analysis*
Air particulates: Continuous sampler in Gallup and a cascade impactor near clean-up crews.	8	Aug. 22, 1979 to Jan. 4, 1980	Uranium, Th-230, Ra-226, Pb-210, Po-210.
Vegetation and produce: Native vegetation and corn growing along the Puerco River.	22	Nov. 1979	Uranium, Th-230, Ra-226, Pb-210, Po-210.
Gamma Radiation: Aerial survey.	Continuous reading	Sept. 29, 1979	Gamma radiation exposure rates.
Ground survey.	252	Aug. 4-7, 1979	Gamma radiation exposure rates.
Livestock: Sheep, goats, cattle collected from Puerco River area and back-ground area.	11	Autumn 1979	Bone, liver, kidney, spleen, muscle, tested for uranium, Th-230, Ra-226, Pb-210, and Po-210.

* Uranium-238 = U-238, Thorium-230 = Th-230, Radium-226 = Ra-226, Lead-210 = Pb-210 and Polonium-210 = Po-210.

3.0 EVALUATION OF DATA

3.1 Surface Water

The release of uranium mill waste to the Puerco River system caused dramatic and immediate changes in stream water quality. The acidity, salinity and radioactivity of the Puerco River were suddenly increased. However, natural recovery processes began soon after the spill. By mid-August, about one month after the spill, dissolved substances in the Puerco River had regained prespill concentrations. Nevertheless, for at least one year after the spill traces of spill contamination were still evident in sediments suspended in the Puerco River by high flows.

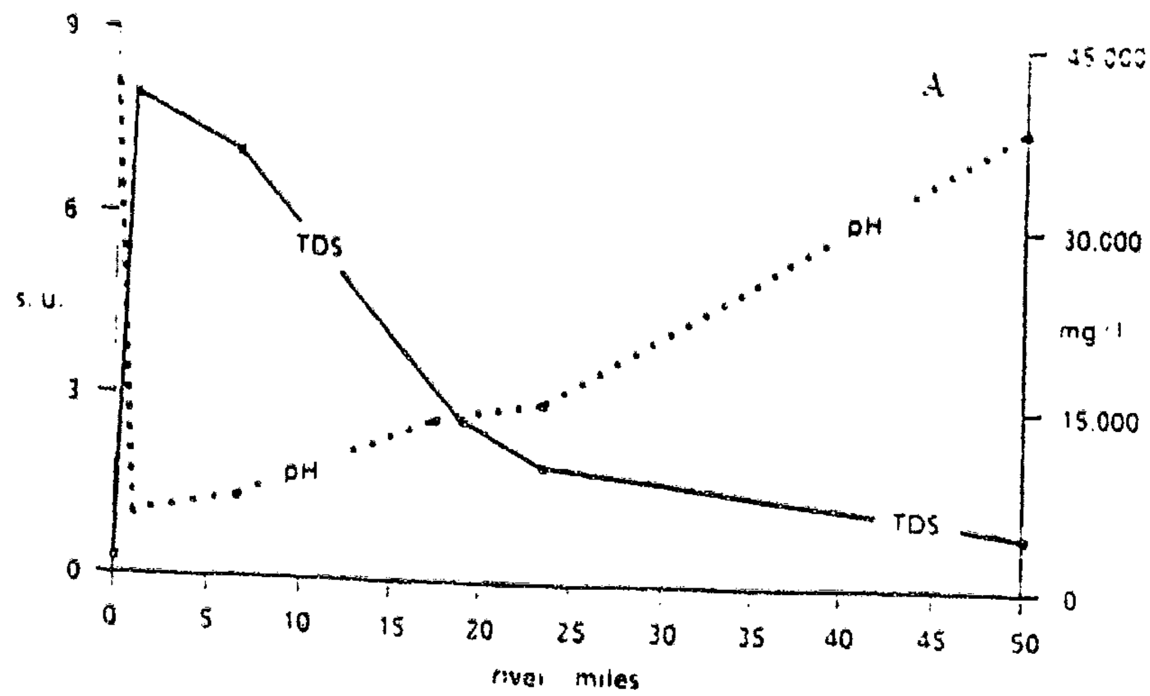
On the day of the spill, the water sample with the greatest measured contamination level was collected at the State Highway 566 bridge, approximately five miles downstream from the tailings breach (see Figure 2.1). Comparison of this sample with prespill data (Figure 3.1) showed that the concentrations of many radionuclides, metals and common salts increased by factors of ten or more.

As the spill traveled downstream the acid waste was neutralized and concentrations of many dissolved substances decreased. Prolonged contact with alkaline soils and sediments caused the acidity of the spill to abate by the time it reached the Arizona border on the evening of July 16. As a result of neutralization, levels of many dissolved metals and radionuclides decreased (Figure 3.2). Radium-226 and lead-210, for example, were quickly removed from solution by processes such as chemical precipitation and adsorption to silts and clays in the channel. These contaminated sediments were slowly dispersed by subsequent high flows in the Puerco River and gradually diluted with "clean" sediments.

In parts of the river system, neutralization was slow because of the large amount of contaminated liquids, sediments and salts in the channel margins. Evidence of this residual contamination was seen immediately after the spill when Puerco River terraces dried out, leaving the arroyo bed covered with yellow salt precipitates. Laboratory tests performed on these salts disclosed that they were highly water soluble and contained metals and radionuclides that could be easily remobilized by subsequent high flows. As predicted, the salt crystals were dissolved by the first thunderstorm runoff on August 7, 1979. During the increased streamflow on August 8, increases in thorium-230, lead-210, uranium, molybdenum, selenium and magnesium concentrations were observed in the Puerco River at Gallup.

It was only after the thunderstorm of August 7 and another storm on August 12 that the Puerco River regained general prespill chemistry at Gallup. Thunderstorm runoff flushed out the contaminated salts and liquids that had occupied arroyo terraces and had delayed recovery of surface water quality. Acidity, salinity and radioactivity at low flows were thus returned to prespill levels by about mid-August (Figure 3.2). Only in subsequent runoff events in 1980 were traces of spill contaminants noted in surface water.

Figure 3.1. Pollutant concentrations in the Puerco River between the UNC spill site and the Arizona state line, July 16, 1979. Note neutralization downstream.



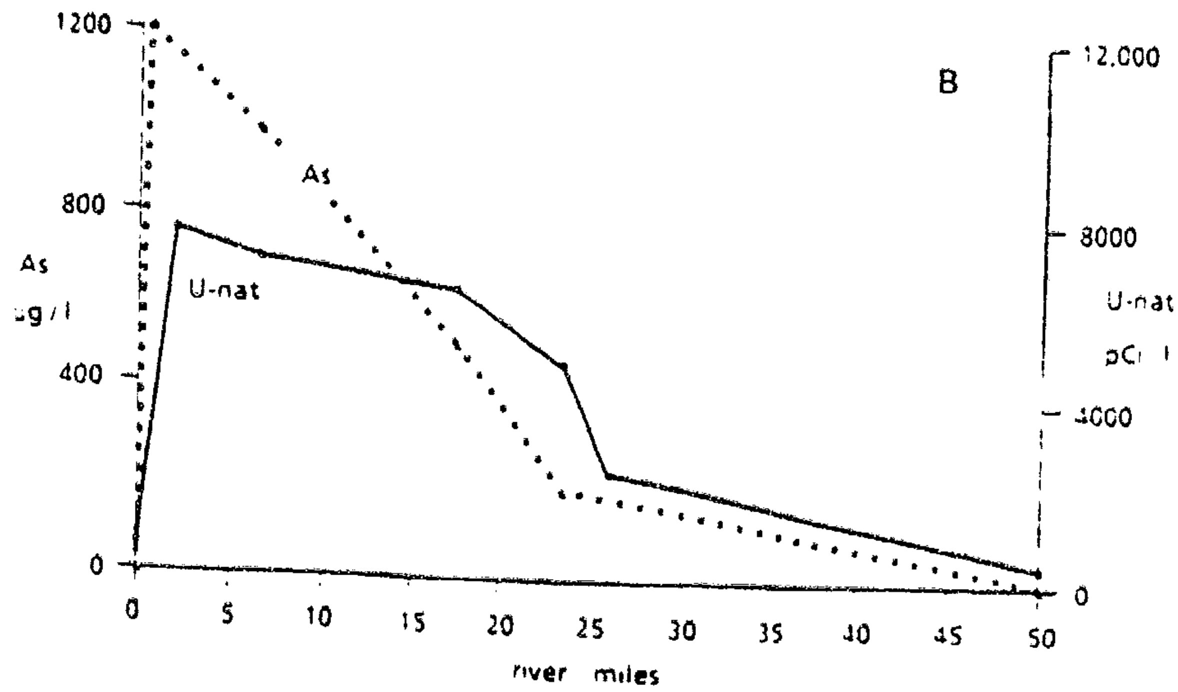


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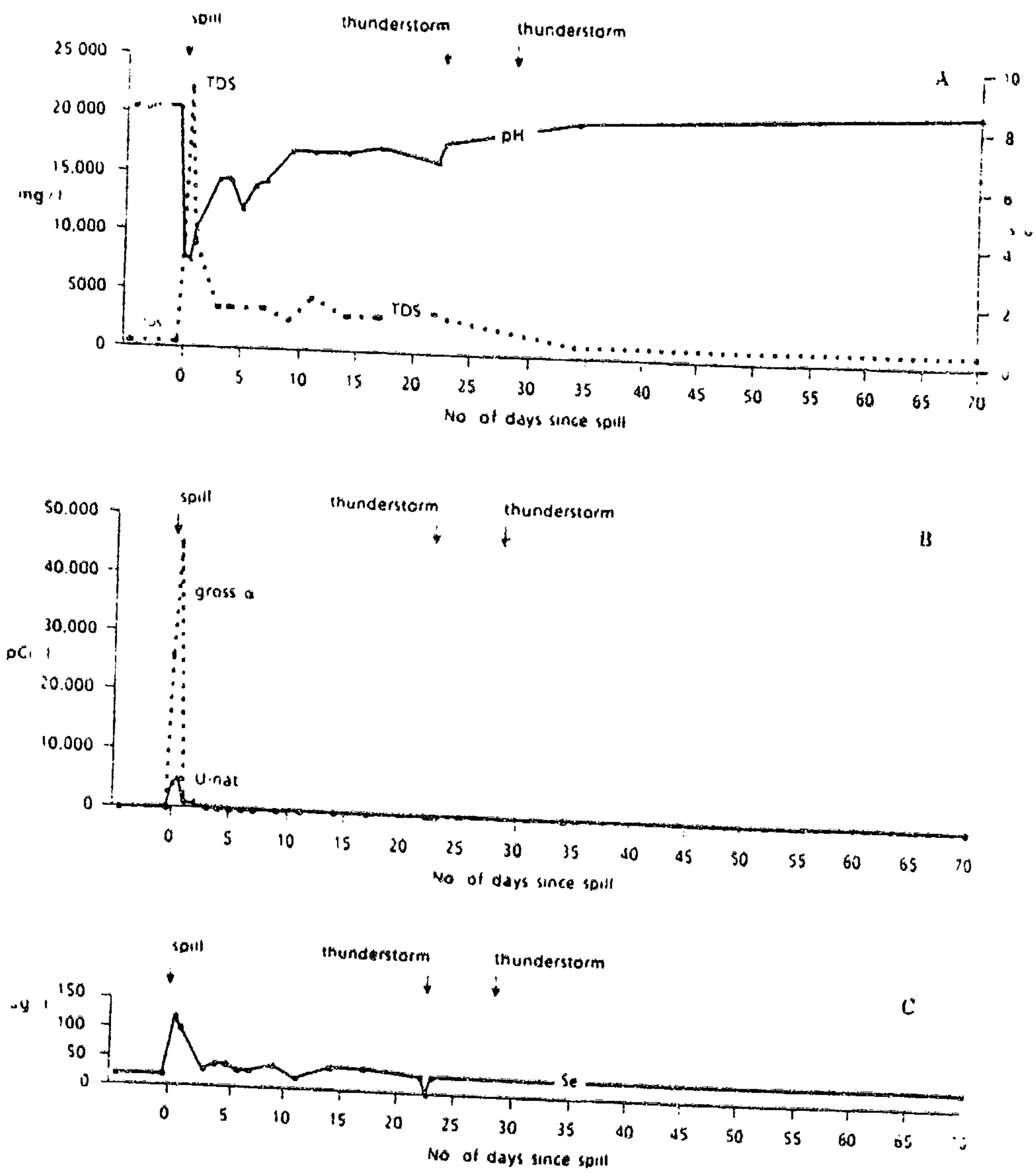
Figure 3.2. Surface Water Concentrations Through Time.



Present water quality conditions in the Puerco River are virtually identical to prespill conditions. Examination of Figure 3.2 suggests that for most parameters spill effects are no longer evident. Surface water quality is now primarily influenced by uranium mine dewatering effluents and natural runoff.

The dewatering effluents and natural runoff that now dominate surface water flows contain environmentally significant levels of radioactive lead, radium and uranium, as well as elemental lead, selenium and molybdenum. Concentrations of these constituents in Puerco River water pose a number of questions regarding the safety of the water for various uses (Chapter 4). Most of these substances come from uranium mine dewatering effluents. However, natural sources of radioactive and elemental lead may contribute significantly to observed levels.

Metals and radionuclides are found naturally in soils along the Puerco River. Some of these substances bind strongly to clay particles in soil and sediment. Thus, during times of intense rainfall, runoff and soil erosion, increasing stream turbidity causes increasing concentrations of attached metals and radionuclides. For example, lead-210 sometimes exceeds maximum permissible concentrations (MPCs) under turbid flow conditions (18). However, MPCs legally apply only to discharges from facilities licensed under New Mexico Radiation Protection Regulations (19); MPCs do not control mine dewatering effluents or natural runoff.

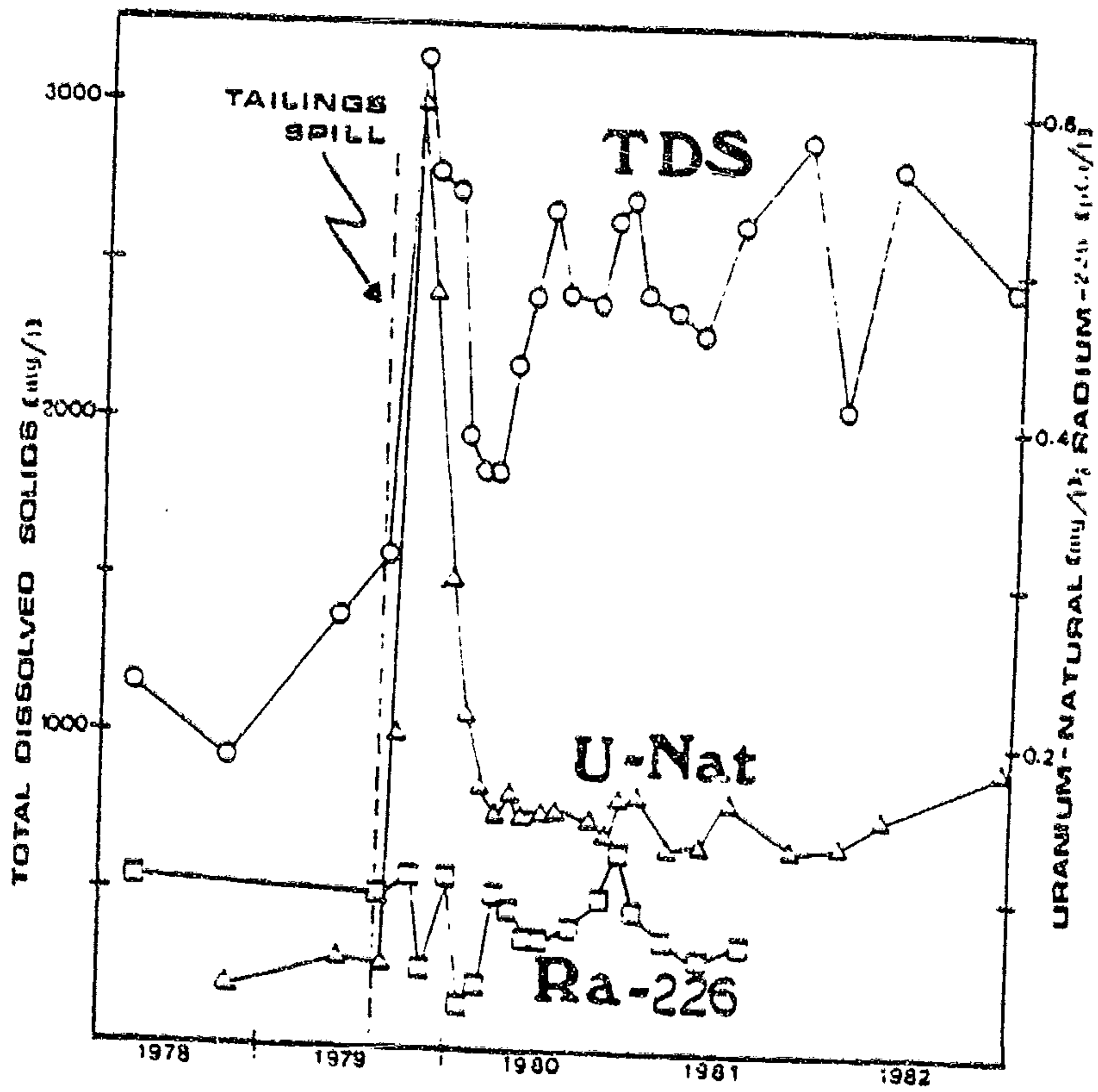
3.2 Ground Water

Results of EID's ground-water quality testing program show that spill impacts are restricted to shallow ground waters in the Puerco River alluvium. These impacts are limited in areal extent and are variable with regard to water quality. Increases in salinity and radioactivity in alluvial sediments near the Puerco River have been detected. However, currently-used public and private water supplies in the area, most of which utilize deep sandstone aquifers, were not affected by the spill.

Review of prespill data and interpretation of geochemical analyses of prespill and postspill data suggest that the spill has slightly increased the salinity and radioactivity of the shallow ground water (Figure 3.3). The salinity change consists of increases in sodium and sulfate concentrations. These concentrations, although sometimes elevated above background, are usually within the range found in native Puerco River valley ground waters (Figure 3.3F). The increase in radioactivity is principally due to uranium. Uranium concentrations, although clearly elevated above background, are usually within the range exhibited by Puerco River valley ground waters affected by dewatering effluents (Figure 3.3B).

For many test wells and private wells, impacts due to the spill can be neither conclusively demonstrated nor absolutely denied for three reasons. First, background data indicate that native ground waters have variable quality that sometimes resembles spill material (Figure 3.3C,D) and may react unpredictably with spill material. Second, dewatering effluents have infiltrated to the alluvial aquifer and have

Figure 3.3. Ground Water Quality in Well "Gallup-3" Before and After the Spill.



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locally affected ground water quality in a manner that may be confused with spill contamination (Figure 3.3A,B). Third, the alluvium contains variable amounts of clay and therefore has a varying ability to chemically and physically remove contaminants from percolating waters. Consequently, a few test wells clearly have been affected by the spill, while others, apparently, have not. At most, only a few contaminants were elevated above natural conditions in those test wells affected. Two examples of contamination of shallow ground water by spill material are given below.

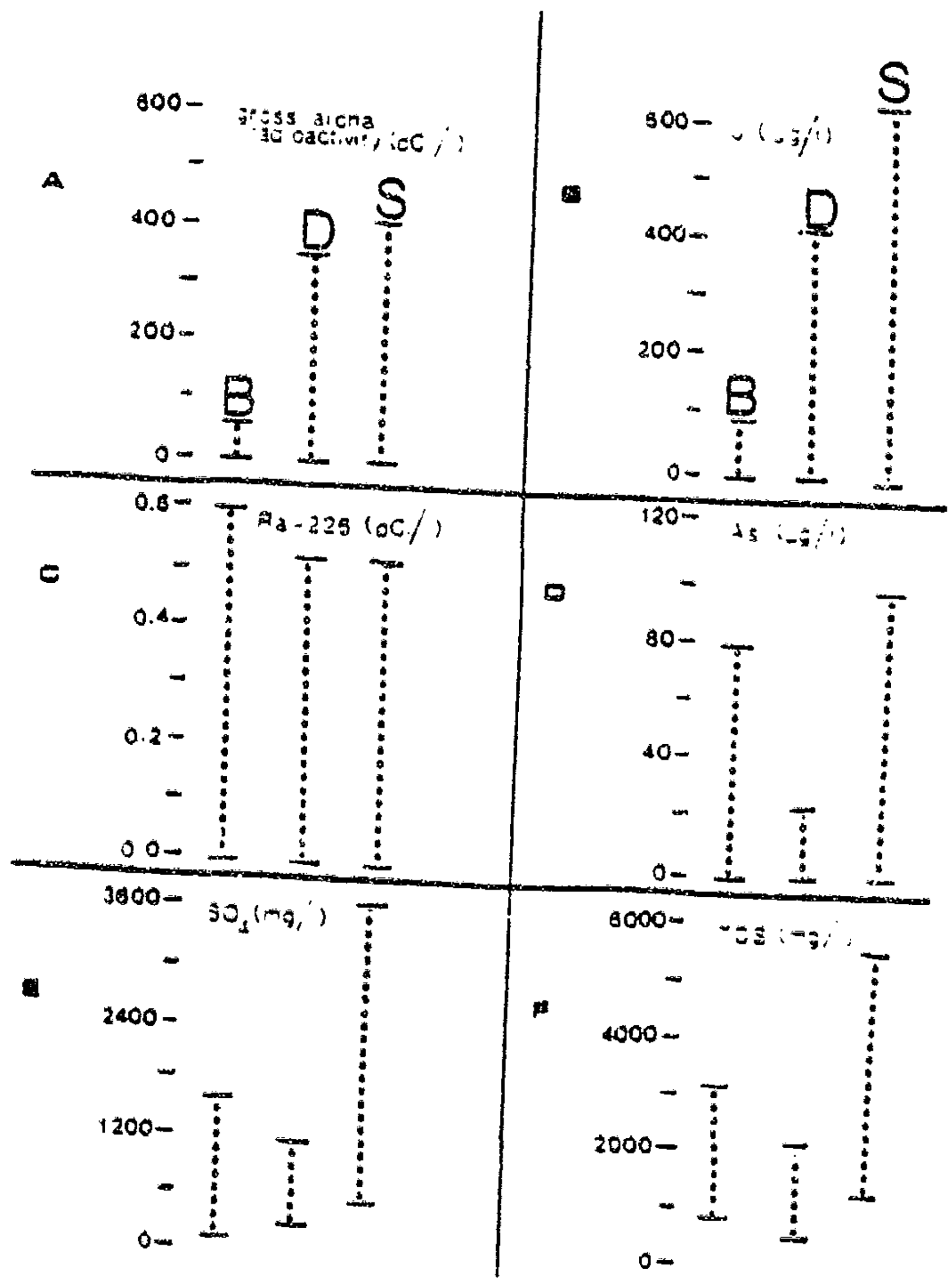
Three miles east of Gallup, water level and water chemistry responses to the tailings spill were detected in a group of EID test wells that was installed before the spill. Less than one week after the spill, ground water levels rose in four wells located within 200 feet of the Puerco River. These water level changes indicated that some of the tailings liquid had infiltrated into the valley sediments. Although nearly identical water level changes were measured in all four wells, only one well showed a significant change in ground water quality. Compared to prespill averages, well "Gallup-3" showed increases in uranium of 10 times (10x), gross alpha radioactivity (20x), barium (8x), sulfate (3x) and calcium (3x). Other contaminants associated with the spill, radium-226 for example, did not increase appreciably in concentration. Figure 3.4 illustrates the changes over time for three contaminants in "Gallup-3."

Results of the U.S. Environmental Protection Agency testing program (6) also showed variation in ground water quality responses to the spill. This program tested water from shallow wells along the Puerco River from above Church Rock downstream to Sanders, Arizona; these wells were privately owned and most were used for domestic purposes or livestock watering. Of the seven wells tested, only an unused well in Lupton, Arizona showed any indication of spill-related contaminants. Sulfate concentrations in this well began increasing in May 1980. By January 1981, sulfate concentrations had stabilized at about three times background concentrations. Although the U.S. Environmental Protection Agency did not conclude that spill contamination had occurred, the pattern of water quality changes in the Lupton well was consistent with the pattern of contamination observed in "Gallup-3."

The vulnerability of public and private wells to contamination from the spill depends primarily on their depth. EID tested drinking water supply wells in Gallup, Manuelito, Mentmore and Sunnyside Trailer Park and found no changes in water quality. These wells are drawing water from sandstone or limestone, usually from great depth. Because these wells are hydrologically and geologically protected from water in the channel and in the alluvium, it is highly unlikely that spill contaminants will ever affect these wells.

Private wells drawing water from the alluvium, such as livestock well 16K-340, also have experienced no significant change in water quality to date. However, because they tap the locally-contaminated alluvial aquifer, contaminants migrating from the spill may influence their water quality at some time in the future.

Figure 3.4. Chemical concentrations in EID test wells representing background, or natural ground water quality (B), contamination by mine dewatering effluents (D), and contamination by spill fluids (S).



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3.3 Channel Sediments

A large volume of surface sediment in the Puerco River channel was contaminated through contact with released tailings material. In order to determine the extent of contamination, it was necessary to determine natural background conditions. Therefore, samples were taken in several areas that were not contaminated by the spill. These sites were on the bank above the Puerco River, on the Hogback just east of Gallup, in Pipeline Arroyo upstream from the release and in the Puerco River upstream from the Pipeline Arroyo confluence (Figure 2.1).

The main sampling effort in September and October 1979 showed that only thorium-230 and lead-210 were elevated above background concentrations (Table 3.1, Figure 3.5). Thorium and lead were particularly elevated in standing pools, where evaporation had concentrated contaminants. Lead-210 levels were most elevated in the first few miles below the dam break, while thorium-230 was most elevated farther downstream. Uranium-238 and radium-226 were not elevated above background levels.

Core samples showed that radionuclide concentrations decreased with depth. Most contaminants were found within the first foot of depth, whereas almost no contamination was found below two feet.

Table 3.1. Mean radionuclide concentrations (pCi/g) in Puerco River sediments and background sediments collected in 1979.

Radionuclide	Background	Puerco River
U-238	2.44 (17)*	3.24 (116)
Th-230	0.75 (78)	27.49 (657)
Ra-226	1.29 (60)	0.49 (579)
Pb-210	1.70 (78)	2.78 (657)

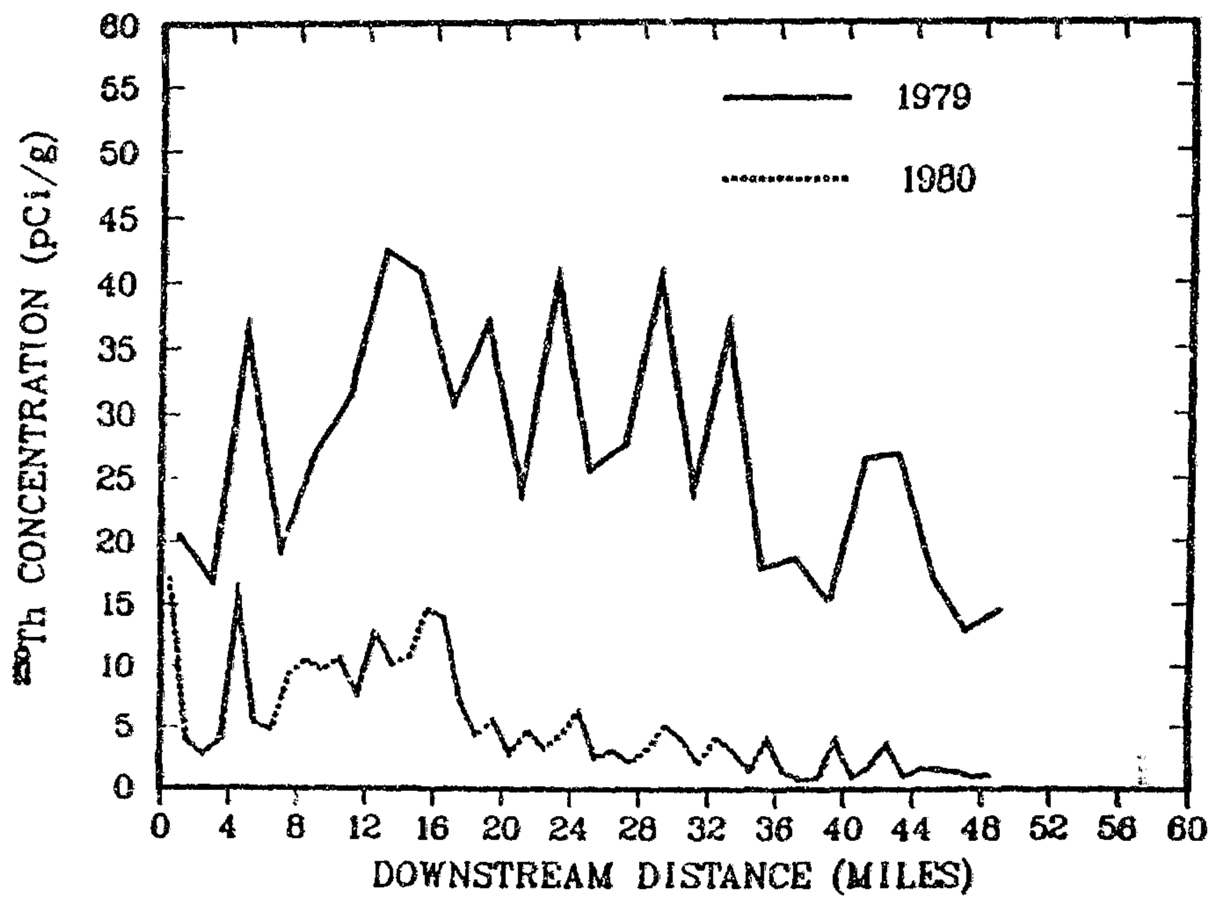
* Number of samples is given in parenthesis.

Resampling of Puerco River sediments in 1980 demonstrated that thorium-230 levels had decreased by 70 percent and lead-210 levels by 50 percent since 1979 (Figure 3.5). The decreases were most likely due to dilution with uncontaminated sediments.

3.4 Air Particulates

Radionuclides in the spilled material could have potentially affected air quality. As sediment in the Puerco River channel dries out, it can be suspended in the air as dust. Contaminated dust can then be inhaled by people and animals.

Figure 3.5. Concentrations of thorium-230 in Puerco River sediments decline with time and with distance downstream from the spill site.



In order to determine the extent of this potential hazard, a continuous air sampler was placed on the bank of the Puerco River in Gallup. The sampler was located at the downwind end of a long, straight reach of the Puerco River oriented in the direction of prevailing winds. Any contaminated dust, if present, would have been detected. However, twelve weeks of continuous sampling after the spill showed only background levels of uranium, thorium-230, radium-226 and lead-210.

A cascade impactor was stationed in the Puerco River arroyo to determine occupational exposure to UNC crews removing contaminated sediment. Dust levels in the air were five times the annual average concentrations in Gallup because of mechanical suspension by earth-moving equipment at the site. Most of this dust was fine material that could be easily inhaled. The thorium-230 activity of this material (16.3 pCi/g) was clearly in excess of the background level (1.6 pCi/g). Uranium, radium-226 and lead-210, however, remained at background levels. Doses calculated from the occupational exposure are given elsewhere (20).

3.5 Vegetation and Produce

Native grasses, shrubs and corn samples collected along the Puerco River by EID contained radionuclide concentrations that fell within the range of reported background values for the region (21). Vegetation collected by UNC along the arroyo bottom showed levels of thorium-230 and radium-226 that were elevated, but not statistically above reported background values.

3.6 Gamma Radiation

Radioactive spill contaminants present in arroyo sediments posed a potential threat of exposure to penetrating gamma radiation. However, neither an aerial nor a ground survey of the area detected any gamma radiation levels attributable to the spill. The UNC tailings area and ore storage areas at nearby mines were easily detected, but no gamma activity above background was found in the channel. This was not surprising since the major radionuclides present in sediments (thorium-230 and lead-210) have weak gamma emissions. Radium-226 has a detectable emission, but it was not present in concentrations above background in Puerco River sediments (Table 3.1).

3.7 Livestock Tissue

Livestock along the Puerco River have been exposed to radionuclides from several sources: mine dewatering effluents, natural runoff and spill materials. In addition, radioactive radon gas is emitted to the atmosphere from the UNC facility and from native soils. Radon then decays to particulate lead-210, which can be deposited on plants. Livestock may then be exposed to this radionuclide through consumption of local vegetation.

Animals that were exposed to Puerco River water had higher concentrations of radionuclides in their tissues than control animals. However, tissues from animals exposed only to mine dewatering effluents and natural runoff also had elevated levels. Lead-210 and radium-226 concentrations appeared to be directly related to the age of the animal (4, 5). Furthermore, there is an apparent build-up of lead-210 in bones of local livestock. These two pieces of evidence suggest that observed radionuclide concentrations have resulted from prolonged ingestion of contaminants prior to the spill. Although unlikely, long term consumption of resuspended spill contaminants may also prove to be an important contributor to radionuclide concentrations in livestock tissues.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

There are several ways that spill contaminants could have affected people in the area. The most obvious way is through direct contact with spill materials. However, such contact could only have occurred within the first few hours after the spill.

Long term exposure to residual materials left in the streambed by the spill is also of concern. Gamma radiation, inhalation of contaminated dust and ingestion of contaminated water, meat, milk and vegetables are several means by which spill contaminants could affect local residents. These various hazards are evaluated below.

4.2 Direct Contact

Contact with the mill waste during or immediately after the spill was a potential health hazard since external contact with spill materials may have occurred. However, the U.S. Centers for Disease Control, in cooperation with the Church Rock community, found no documented human consumption of spill materials. To confirm this, six persons most likely to have been exposed to spill materials were tested at Los Alamos National Laboratory (4, 5). None of the six subjects were found to have above normal amounts of radioactive materials in their bodies.

The validity of the above tests has been questioned by some groups, such as Southwest Research and Information Center (9). It is our opinion that only limited conclusions can be drawn from these test results. Since the potentially exposed subjects were not tested until one month following the spill, any ingested radionuclides would have been eliminated in the feces prior to testing. In addition, whole body counting was inadequate for detecting principal radionuclides released by the spill. Nevertheless, valid urinalyses failed to detect abnormal amounts of radioactive materials. Despite the limited conclusions that can be drawn from the tests performed, further testing of area residents is not recommended. Additional tests would be inconclusive due to the amount of time that has elapsed since any exposure to the spill.

4.3 Surface Water

EID has concluded that the Puerco River was seriously degraded because of the spill. However, potential hazards associated with the spill were minimized because spill contamination was brief and the river was not intensively used by area residents.

Of perhaps greater significance to local residents is the quality of the dewatering effluents and natural runoff normally found in the Puerco River. Although these waters are low in dissolved solids, they contain significant concentrations of certain radionuclides and toxic metals.

These concentrations are high enough for EID to discourage unlimited use of the water for human consumption, livestock watering or irrigation.

Surface waters in New Mexico are governed by general standards (22), which incorporate Part 4 of the New Mexico Radiation Protection Regulations (19). Combined concentrations of uranium, thorium-230, radium-226, lead-210 and polonium-210 in the Puerco River approach or exceed limits specified by these standards. In addition, total alpha radioactivity continuously exceeds criteria established to protect drinking water supplies (23). The intensive use of Puerco River water for drinking, irrigation or livestock watering may increase cancer risk. The radiological hazard can be reduced by removing suspended silts and clays from the water.

Some toxic metals are also present in the Puerco River in quantities that exceed recommended levels for various uses:

1. For human consumption of Puerco River water selenium is of concern. Concentrations of this element usually exceeded the federal drinking water standard of 0.01 mg/l (23) by two to five times. However, the State of New Mexico regulatory limit of 0.05 mg/l for groundwater (24) has only been exceeded once. Although the Puerco River is not subject to these regulatory limits, the comparison is useful.

2. For livestock water, the National Academy of Sciences recommended a maximum concentration of 0.1 mg/l for total lead (25). This concentration was exceeded more than 80 percent of the time under turbid runoff conditions; concentrations of more than 10 times the recommended level were observed. Under low flow conditions, lead concentrations are below the recommended level for livestock. It is apparent that removal of suspended sediment therefore removes virtually all of the lead.

3. Irrigation criteria for total selenium of 0.020 mg/l (25) and total molybdenum of 0.150 mg/l (26) were exceeded in the Puerco River about 90 percent and 45 percent of the time respectively. Average concentrations of these constituents were 0.028 and 0.283 mg/l respectively. New Mexico regulations limit dissolved molybdenum in irrigation waters to 1.0 mg/l (24). The highest concentration of dissolved molybdenum measured in the Puerco River to date was 0.8 mg/l. Selenium is directly poisonous to agricultural crops. In addition, plant tissues may accumulate levels of molybdenum and selenium that are toxic to livestock.

Based on the above conclusions, EID discourages indiscriminate use of Puerco River water. Although occasional use of this water may not be harmful, local residents should use cleaner sources of water whenever possible. If use must be made of Puerco River water, the chemical quality of the water can be vastly improved by removal of suspended silts and clays through settling or filtration.

At this time, it is not possible for EID to make more detailed recommendations regarding specific uses of the Puerco River. Further study is required to ascertain the contributions of radiological and chemical contaminants from natural sources as well as uranium industry sources. When ongoing EID studies are complete, appropriate administrative or regulatory efforts should be made to control contaminants where feasible.

4.4 Ground Water

Although the spill has degraded ground water quality in limited areas near the Puerco River, it has not significantly increased health risks to ground water users in the region. No spill-related change in water quality has been detected in any well along the Puerco River currently being used for drinking water or for livestock supply. Spill impacts appear to be restricted to slight contamination of a few shallow EID test wells, and possibly a shallow private well in Lupton, Arizona that is no longer in use.

While no domestic use is made of the test wells, it is useful to examine the quality of water in these wells with respect to potential uses. Fewer than one-third of the EID test wells produced water with chemical concentrations which exceeded federal drinking water standards. In those wells, concentrations of gross alpha radioactivity, selenium and arsenic exceeded federal standards (23) by a factor of two or less. However, most of those concentrations were less than State of New Mexico ground water standards (24). Salinity concentrations almost always exceeded federal and state standards or guidelines established for aesthetic concerns, such as taste. These standards have been exceeded by as much as ten times.

With respect to use of the water for livestock supply, concentrations of selenium, gross alpha radioactivity and salinity exceeded recommended levels (25) in 5 percent, 25 percent and 10 percent of the test wells, respectively. Recommended irrigation levels (25) were exceeded by both selenium and gross alpha radioactivity concentrations in 20 percent of the test wells sampled. Most levels in excess of the livestock and irrigation guidelines exceeded these criteria by a factor of two or less.

There are two scenarios in which spill contaminated ground water may affect ground water users in the future. First, while ground water moves slowly and contamination is slight and confined to limited areas, spill contaminants may eventually migrate to shallow wells currently being used for domestic purposes or for livestock supply. Should this occur, the resulting increases in salinity and radioactivity probably would be minor and would not affect existing use of the waters. Second, a newly-drilled shallow well could intercept zones having marginal or unsuitable water quality. EID data indicate that, in most cases, this potential problem would be avoided by drilling deeper and sealing off the upper 100 feet of the alluvium.

Uranium mine dewatering effluents probably have had a greater influence on the quality of the shallow ground water than has the spill.

The volume of mine effluents available for recharging the shallow ground ground water far exceeds the volume of mill waste released during the spill. In 1979 alone, uranium mines discharged to the Puerco River nearly 30 times as much water as was released by the spill. Most EID test wells and other shallow wells produce mixtures of native ground water and infiltrated dewatering effluents.

Because of uncertainty in predicting shallow ground water quality in the Puerco River valley, EID recommends that reliance upon shallow ground water not be significantly increased in the future. Existing public and private wells drawing water from the alluvium should be tested annually by appropriate authorities for salinity and gross alpha radioactivity. For wells drawing water from sandstone or limestone aquifers, existing testing programs conducted under the federal Safe Drinking Water Act are sufficient to detect contaminants derived from the spill or from dewatering effluents. New wells drilled in the Puerco River valley should be designed to draw water from sandstone or limestone aquifers. If an alluvial well is necessary, the upper 100 feet of alluvium should be sealed off.

4.5 Livestock

Much concern has been voiced regarding the potential contamination of Puerco River area livestock due to the spill. Local livestock may have been exposed to spill materials. However, these animals have also been chronically exposed to dewatering effluents and natural runoff. Tissues from animals exposed to all sources tended to have higher concentrations of lead-210, polonium-210 and radium-226 than tissues from control animals. These radionuclides tend to accumulate preferentially in the liver, kidney, spleen and bone of livestock. Following human consumption of exposed livestock, these same tissues in humans would receive the highest radiation dose.

Radiation doses to man were calculated using actual livestock tissue data (4.5). Whole body dose was 1.4 and 7.8 mrem/year of exposure from consumption of control and exposed animals, respectively. Human bone received the highest dose of any organ with a yearly exposure of 21 mrem/year from consumption of exposed animals. Liver and kidney received 3.4 and 11.5 mrem/year of exposure. Doses from ingestion of control animal tissues ranged from 1.0 to 6.8 mrem/year of exposure.

One exposed goat sample had a very high radium-226 value in muscle. However, this sample must be questioned since (1) dissection of this animal occurred under uncontrolled conditions, (2) the radium-226 concentration for muscle was 70 times higher than for any other animal and (3) no radium-226 was detected in either the liver or kidney of this animal. This evidence strongly suggests that the muscle sample was contaminated during the sampling procedure. Therefore, this sample was not included in any statistical analyses, pending further study of radionuclide concentrations in livestock.

Based on the limited data available to date, the radiation risk from eating an average year's supply of meat (78 kg) from Puerco River area animals seems to be about the same as the increased risk from cosmic radiation incurred by moving from sea level to 5000 feet in elevation.

Although doses for this human food chain pathway are elevated, accurate evaluation of risk to man is hampered due to small sample size and anomalous results. It is therefore recommended that a more intensive livestock monitoring program be instituted so that doses can be better defined. Such a program has recently been initiated by EID.

It is not possible at this time to assign the observed radionuclide concentrations in livestock to the UNC spill. Lead-210, one of the most abundant radionuclide contaminants in livestock tissues, is also present in mine dewatering effluent and natural runoff waters; lead-210 is also deposited on forage as a decay product of atmospheric radon-222. Moreover, lead-210 levels in animal bone tissues suggest prolonged, rather than short-term, exposure. Such a sampling program as suggested above could also help to identify the source(s) of radionuclides in livestock.

4.6 Additional Exposure Routes

Measured levels of radionuclides in air, native vegetation and garden produce along the Puerco River were not above background levels. Similarly, gamma radiation levels were not above background levels. It was concluded that the additional dose to man from exposure to spill materials from these routes was insignificant. Avoidance of the arroyo during windy conditions was therefore considered to be of minor importance and unnecessary for the protection of human health. No further action is necessary.

4.7 Long Term Radiation Impacts

In addition to calculating radiation doses to man from sampling data, a computer modeling assessment was conducted to predict doses resulting from a future worst case scenario. All exposure routes to man were addressed simultaneously to provide a total dose estimate.

The Uranium Despersion and Dosimetry (UDAD) computer code (17) was used to predict radiation doses to man. Basic data used as input parameters for UDAD included radioactive contaminant levels for soil and stream sediments as well as meteorological information on wind velocity, direction and frequency. It was conservatively assumed that exposed individuals spent 100 percent of their time 20 meters from the Puerco River. It was also assumed that the river bed was completely dry and therefore subject to maximal dusting conditions and that radionuclide concentrations in stream sediments remained at their highest postspill levels throughout the entire year of hypothetical exposure. These assumptions maximized the inhalation of contaminated dust and therefore predicted doses were also maximized for this worst case scenario.

The radiation doses received over a fifty-year period from one year of exposure to spill materials (fifty-year dose commitments) were calculated by UDAD and are shown in Table 4.1. Of all the human body tissues, bone received the highest dose, primarily from the inhalation of thorium-230. The inhalation route was therefore predicted to be the most important contributor to total dose. Compare this outcome with the results of calculations based on measured air particulate data (sections 3.4 and 4.6).

Table 4.1. Radiation doses to human organs calculated by the UDAD computer code.

Exposure Route	Fifty-Year Dose Commitment (mrem/year of exposure)				
	Whole Body	Bone	Kidney	Liver	Lung
Inhalation	0.55	19.5	5.49	1.23	0.02
Ingestion	0.52	6.45	5.63	1.60	0.52
Gamma	0.06	0.07	0.06	0.06	0.18
Total	1.13	26.0	11.2	2.89	0.72
Regulatory Limit	500	2900	1500	1500	1500

Consumption of meat and vegetables grown in the Puerco River area was also predicted to be of importance. Despite worst case assumptions, however, predicted ingestion doses were smaller than those calculated from actual livestock tissues (sections 3.7 and 4.5). This is probably because the UDAD code only considers consumption of livestock muscle tissue, and not consumption of more contaminated organs such as liver, kidney and bone.

Fifty-year dose commitments from spill related gamma radiation were calculated by UDAD and were predicted to be extremely small. For comparative purposes, doses resulting from regulatory limit concentrations (19) were given in Table 4.1. The maximum possible doses estimated by UDAD for the UNC spill were clearly far below regulatory limits designed to protect human health.

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