Technical Note
ORP/LV-75-4

SUMMARY OF GROUND-WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING IN THE GRANTS MINERAL BELT, NEW MEXICO

Robert F. Kaufmann

Gregory G. Eadie

Charles R. Russell

August 1975

U.S. Environmental Protection Agency
Office of Radiation Programs
Las Vegas Facility
Las Vegas, Nevada 89114

PREFACE

The Office of Radiation Programs of the Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and non-ionizing radiation and to promote development of controls necessary to protect the public health and safety.

Within the Office of Radiation Programs, the Las Vegas Facility (ORP-LVF) conducts in-depth field studies of various radiation sources (e.g., nuclear facilities, uranium mill tailings, and phosphate mills) to provide technical data for environmental impact statement reviews as well as needed information on source characteristics, environmental transport, critical pathways for population exposure, and dose model validation.

This report summarizes the results of the ground-water study conducted by ORP-LVF during February and March 1975 in the Grants Mineral Belt area of New Mexico. The final technical report, "Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico", will be published at a later date as EPA-520/6-75-013.

Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks
Director, Office of
Radiation Programs, LVF

PREFACE

The Office of Radiation Programs of the Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and non-ionizing radiation and to promote development of controls necessary to protect the public health and safety.

Within the Office of Radiation Programs, the Las Vegas Facility (ORP-LVF) conducts in-depth field studies of various radiation sources (e.g., nuclear facilities, uranium mill tailings, and phosphate mills) to provide technical data for environmental impact statement reviews as well as needed information on source characteristics, environmental transport, critical pathways for population exposure, and dose model validation.

This report summarizes the results of the ground-water study conducted by ORP-LVF during February and March 1975 in the Grants Mineral Belt area of New Mexico. The final technical report, "Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico", will be published at a later date as EPA-520/6-75-015.

Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks
Director, Office of
Radiation Programs, LVF

TABLE OF CONTENTS

FIGURES

TABLES

Tables | Page

TABLES

PURPOSE OF STUDY

In September 1974, the State of New Mexico Environmental Improvement Agency (NMEIA) made a request of Region VI of the U.S. Environmental Protection Agency (USEPA) to conduct a definitive survey of the Grants Mineral Belt area (Wright, 1974). At this time, a summary report evaluating the problem areas in the study area was also prepared by Region VI (Keefer, 1974). Briefly, the water-quality impacts associated with ongoing and projected uranium mining and milling in the Grants Mineral Belt of New Mexico were unknown. Whether a problem existed was questionable but worthy of investigation because of the toxic nature of the effluents and their persistence in the environment. The study areas of most concern were located near Churchrock, Ambrosia Lake-Grants, and Laguna-Paguate.

In late November 1974, the Office of Radiation Programs-Las Vegas Facility (ORP-LVF) and the National Enforcement Investigations Center (NEIC) were requested by Region VI to provide direct assistance to the NMEIA to conduct the study.

Representatives of ORP-LVF, NEIC, and NMEIA completed a field reconnaissance of the study area during the week of January 24, 1975. Industry representatives were contacted, arrangements were made for site access, and sampling locations and collection schedules were finalized after reviewing company monitoring programs. Study plans were prepared by both ORP-LVF and NEIC defining study participants, responsibilities, and specific analyses to be completed per location by each laboratory.

Subsequent meetings between the three participating agencies resulted in a final study plan which defined the following study objectives to the satisfaction of NMEIA (Bond, 1975):

1. Assess the impacts of waste discharges from uranium mining and milling on surface waters and ground waters of the Grants Mineral Belt.

2. Determine if discharges comply with all applicable regulations, standards, permits, and licenses.

3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures, and reporting requirements.

4. Determine the composition of potable waters at uranium mines and mills.

5. Develop priorities for subsequent monitoring and other follow-up studies.

Ground-water aspects of objectives 1, 3, and 5 were the responsibility of ORP-LVF, whereas the remaining objectives were pursued by NEIC.

Actual sample collection began in late February 1975 in the Ambrosia Lake-Bluewater area. It proceeded to Paguate Jackpile and was finally completed in the Gallup-Churchrock area in early March 1975. Laboratory analyses for the trace metals, gross alpha, and radium-226 were completed by NEIC. The other radiological analyses were completed by the Environmental Monitoring and Support Laboratory (EMSL), Las Vegas. Radiometric analyses were assigned the highest priority at each laboratory and were completed in July 1975.

SUMMARY AND CONCLUSIONS

TASK I: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds, (2) mine drainage water that is first introduced to settling lagoons and thence to water-courses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations are observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (<u>in situ</u>) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have

increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

4. Contamination of the Gallup municipal ground-water supply by surface flows, consisting mostly of mine drainage, has not occurred and is extremely unlikely because of geologic conditions in the well field and the depth to productive aquifers. Another well field north of the City will, in no way, be affected by the drainage.

5. With the exception of the areas south and southwest of the United Nuclear-Homestake Partners mill, widespread ground-water contamination from mining and milling was not observed in the study area. Throughout the study area widespread contamination of ground water with radium was not observed despite concentrations of as much as 178 pCi/l in mine and mill effluents. Radium removal is pronounced, probably due to sorptive capacity of soils in the area. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but neither parameter exceeds drinking water standards.

6. Ground water in at least part of the shallow aquifer developed for domestic water supply downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium. Alternative water supplies can be developed using deep wells completed in the Chinle Formation or in the San Andres Limestone. Potential well sites are located in the developments affected and in the adjacent area. A third alternative includes connecting to the Milan municipal system. Further evaluations are necessary to determine the best course of action.

7. Mining practices, per se, have an adverse effect on natural water quality. Initial penetration and disruption of the ore body in the Churchrock mining area increased the concentration of dissolved radium in water pumped from the mines from 0.05 - 0.62 pCi/l to over 8 pCi/l. According to company data, the concentration rose to over 75 pCi/l, or at least 75 times the natural concentration, in the two-year period during which the mine was being developed. The pattern of increasing radium with time, seen in Ambrosia Lake, is being repeated. Ground-water inflow via long holes

in the Kerr-McGee Section 36 mine contains a relatively low concentration of dissolved radium-226. Therefore, much of the radium loading of mine effluent is apparently a result of leaching of ore solids remaining from mucking and transport within the mine. In some cases this could be reduced by improved mining practices, such as provision of drainage channels along haulage drifts.

8. Company data show that seepage from the Anaconda tailings pond at Bluewater averages 183 million liters/year (48.3 million gallons) for 1973 and 1974. The average volume injected for the same time period was 348 million liters/year (91.9 million gallons). Therefore, approximately one-third of the total effluent volume remaining after evaporation (531 million liters/year) enters the shallow aquifer which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage alone introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of the seepage and the injected wastes is not underway.

9. There are indications that waste injected into the Yeso Formation by the Anaconda Company are not confined to that unit as originally intended in 1960. Three nearby monitoring wells, completed in the overlying San Andres Limestone and/or the Glorieta Sandstone, show a trend of increasing chloride and uranium with time. Positive correlations of water quality fluctuations with the volumes of waste injected are a further indication of upward movement. The absence of monitoring wells in the injection zone is a major deficiency in the data collection program.

10. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. According to company data, seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year). This is 29 percent of the influent to the "evaporation ponds" and attests to their poor performance in this regard. Radium and gross alpha in the seepage are 56 pCi/l and 112,000-144,000 pCi/l, respectively. Total radium introduced to the ground water to date is estimated at 0.7 curies. Wells completed in bedrock and in alluvium, and located near watercourses containing mine drainage and seepage from tailings ponds, contain elevated levels of TDS, ammonia, and nitrate. One well, which contained 1.0 pCi/l in 1962, now is contaminated with 3.7 pCi/l of radium. Sorption or bio-uptake of radium is pronounced; hence, concentrations now in ground water are not representative of ultimate concentrations.

11. Water-quality data from 11 wells over a 200-square kilometer area in the Puerco River and South Fork Puerco River drainage basins reveal essentially no noticeable increase in concentrations of radionuclides or common inorganic and trace constituents in ground water as a result of mine drainage. Natural variations in the uranium content of sediments probably account for differences in radium content in shallow wells. Dissolved radium in shallow ground water underlying stream courses affected by waste water is essentially unchanged from that in areas unaffected by mine drainage. None of the samples contained more than recommended maximum concentrations for radium-226, natural uranium, thorium-230, thorium-232, or polonium-210 in drinking water. However, the paucity of sampling points and the absence of historical data make the foregoing conclusion a conditional one, particularly in the reaches of the Puerco River within approximately 10 kilometers downstream of the mines.

12. Four wells sampled in the vicinity of the Jackpile mine near Paguate contained 0.31 to 3.7 pCi/l radium-226. With the exception of the latter value from the new shop well in the mine area, remaining supplies contain 1.7 pCi/l or less radium. The Paguate municipal supply contains 0.18 pCi/l. None of the wells were above maximum permissible concentrations (MPC) for the other common isotopes of uranium, thorium, and polonium. Ground water from the Jackpile Sandstone may contain elevated levels of radium as a result of mining activities. Mine drainage water ponded within the pit contained 190 pCi/l radium and 170 pCi/l of uranium in 1970. The impacts of mining on groundwater quality downgradient from the mining area are unknown due to the lack of properly located monitoring wells. No adverse impacts from mining on the present water supply source for Paguate are expected.

13. Of the 71 ground-water samples collected for this study, a total of 6 had radium-226 in excess of the 3 pCi/l PHS Drinking Water Standard. Two of the 6 involved potable water supplies. One containing 3.6 pCi/l serves a single family and is located adjacent to Arroyo del Puerto and downgradient from the mines and mills in Ambrosia Lake. The second contains 3.7 pCi/l and is used as a potable supply for the labor force in the new shop at the Jackpile Mine.

14. The highest isotopic uranium and thorium, and polonium-210 contents for any potable ground-water supplies sampled in the study area are less than 1.72% of the total radionuclide population guide - MPC as established in NMEIA regulations.

15. The lowest observed concentration (background levels) in ground water are summarized as follows:

Radionuclides	Range (pCi/l)	Average (pCi/l)
Radium-226	0.06 - 0.31	0.16
Polonium-210	0.27 - 0.57	0.36
Thorium-230	0.013- 0.051	0.028
Thorium-232	0.010- 0.024	0.015
U-Natural	14 - 68	35

16. The uranium isotopes (uranium 234, 235 and 238) are the main contributors to the gross alpha result; however, in several determinations, gross alpha underestimated the activity present from natural uranium.

17. No correlation was found between gross alpha content of 15 pCi/l (including uranium isotopes) and a radium-226 content of 5 pCi/l.

18. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g., U-natural and polonium-210). Furthermore, since the gross alpha results have such large error terms, no meaningful determination of percentage of radionuclides to gross alpha can be implied.

19. Gross alpha determinations also failed to indicate the possible presence of lead-210 (primarily a beta emitter) which, because of the lower MPC of 33 pCi/l, may be a significant contributor to the radiological health hazard evaluation of any potable water supply.

20. Radium-226 in ground water is a good radiochemical indicator of wastewater contamination from mines and mills. Due to the low maximum permissible concentration, it also provides a good means for evaluating health effects. Selenium and nitrate also indicated the presence of mill effluents in ground water. Polonium-210, thorium-230 and thorium-232 concentrations in ground water fluctuate about background levels and are poor indicators of ground-water contamination from uranium mining and milling activities.

21. For routine radiological monitoring of potable ground-water supplies, isotopic uranium and thorium and polonium-210 analyses do not appear to be necessary due to their high maximum permissible concentrations (chemical toxicity of uranium may be a significant limiting factor, however).

TASK II: Evaluate the Adequacy of Company Water Quality Monitoring Networks, Self-Monitoring Data, Analytical Procedures, and Reporting Requirements.

1. Company sponsored ground-water monitoring programs range from inadequate to nonexistent. Actual monitoring networks are deficient in that sampling points are usually poorly located or of inadequate depth/location relative to the hydrogeologic system and the introduction of contaminants thereto. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment.

2. Company radiochemical analytical methods are inadequate for measuring environmental levels of radionuclides and have high minimum detectable activities and large error terms. Incomplete analysis of radionuclide contents prevails. Few data are reported on other naturally occurring radionuclides such as isotopic thorium, polonium-210, and radium-228. In some cases, monitoring has been restricted to analysis of radium-226 and natural uranium, without consideration of these other radionuclides or toxic metals.

3. Monitoring of hydraulic and water-quality impacts associated with conventional mining and with solution (in situ) mining is not reported to regulatory agencies. It is likely that such monitoring is limited to meeting short-term economic and engineering needs of the companies rather than addressing long-term, general environmental concerns. As a result, overall impacts on ground water are not routinely determined and reported.

4. Off-site ground-water sampling networks do not utilize wells specifically located and constructed for monitoring purposes. Reliance on wells already in existence and utilized for domestic or livestock use falls short of the overall monitoring objectives (i.e., to determine impacts on ground water and to adjust company operations to acceptable levels). Deficiencies of this type can allow contamination to proceed unnoticed. On-site wells constructed specifically for monitoring are generally not completed to provide representative hydraulic and water quality data for the aquifer most likely to be affected.

5. Proven geophysical and geohydrologic techniques to formulate environmental monitoring networks are apparently not used. Such techniques can assist in specifying sampling

frequencies and provide the basis for adjustment of monitoring and operational practices to mitigate adverse impacts on ground water.

6. Monitoring the effects of the Jackpile and Paguate open pit mines on ground-water quality is nonexistent despite the magnitude of these operations. Drainage water within the pits has contained as much as 190 pCi/1 of radium. Two wells, used for potable supply and completed in the ore body, contain elevated levels of radium, further indicating a need for data to determine what the future impacts might be when mining ceases and before additional programs for heap leaching and <u>in situ</u> mining are implemented.

7. Careful analysis of material and water balances to determine seepage input to ground water for the various tailings disposal operations is not evident. For the Ananconda Company, the method utilized has not been altered in 14 years. For Kerr-McGee, overland flow presents a potential threat to the structural integrity of the retention dams. At the United Nuclear-Homestake Partners Mill, no quantitative estimates of seepage are available.

8. Records of U. S. Atomic Energy Commission (USAEC) inspection reports, mill license applications, seepage reports, etc., on file with the State appear to be incomplete and disorganized. No interpretive summary or review-type reports utilizing the monitoring data reported by industry are available from either the State or the U.S. Atomic Energy Commission files now held by the State. Liberal mill licensing conditions with respect to ground-water monitoring and water-quality impacts were initially established by the USAEC. Subsequently, there has been essentially no review, in any critical sense, of company operations with respect to ground-water contamination. The uranium mining and milling industry has not been pressed to monitor and protect ground-water resources. The limited efforts put forth by industry to date have largely not been reviewed by regulatory agencies at the State and Federal levels.

RECOMMENDATIONS

Action Required

1. Improved industry-sponsored monitoring programs should be implemented and the data made available to State and Federal regulatory agencies. Programs should be designed to detect likely hydraulic and water quality impacts from uranium milling and mining (open pit, underground, *in situ*). Revamped programs, specifically developed by joint concurrence of industry and regulatory agencies, should be incorporated in licenses, where possible. Licenses should specify minimal radiochemical analytical methods for detecting specific radionuclides as well as requirements for participation in quality assurance programs. Specific reporting procedures should include raw data, summary reports, and interpretations of data. Conclusions concerning impacts of operations on ground-water quality and remedial steps taken to abate or eliminate adverse impacts should be prepared. It is essential that the programs developed, as well as the data and interpretive reports prepared therefrom, be critically reviewed by the State to meet continuing regulatory responsibilities.

2. Because seepage from the Anaconda and Kerr-McGee tailings ponds constitutes a significant portion of the inflow to the ponds, it is recommended that seepage control measures be adopted. According to company records, such seepage presently totals some 674 million liters per year. Water budget analyses of the United Nuclear-Homestake Partners tailings pond should be made to determine how much seepage is occurring, and thereby contributing to contamination of the shallow aquifer locally developed for domestic water supplies in two adjacent privately owned housing developments.

3. Improved mining practices should be adopted to reduce the amount of radium leached from ore solids by ground water present in operating mines.

ADDITIONAL STUDIES REQUIRED

1. Studies should be immediately initiated to verify whether the source of ground-water contamination in the Broadview Acres and Murray Acres subdivision is from the nearby uranium mill. An improved monitoring program should be developed to predict contaminant migration and to provide the basis for subsequent enforcement action. Necessary action should be taken to provide potable water for the affected area. Studies should be undertaken to determine the means to prevent continuing contamination.

2. With regard to the Anaconda waste injection program, all available chemical and water level data for pre-injection and post-injection periods should be evaluated to ascertain if waste is migrating out of the Yeso Formation and into overlying aquifers containing potable water. Of particular concern are radium-226 and thorium-230 because of their abundance in the injected fluid. Limited chemical data indicating migration of waste beyond the injection interval necessitate that a thorough re-evaluation be made of the long term adequacy of this method of waste disposal. Construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Because of low MPC values, this is particularly true if increasing concentrations of radium-226 and possibly lead-210 are appearing in the aquifers above the injection zone. The Anaconda Company should also evaluate the current loss of uranium resources to the subsurface through their current disposal technique.

3. Available chemical data for ground-water samples collected by Kerr-McGee from wells located adjacent to Arroyo del Puerto and San Mateo Creek should be evaluated for long-term trends in water quality. Data for the Wilcoxson (P. Harris), Bingham, Marquez, and County Line Stock Tanks wells are of principal concern.

4. Water-quality data from the newly completed monitoring wells peripheral to the Kerr-McGee mill should be cross-checked using non-industry laboratories to determine the extent of contamination in the Dakota Sandstone.

5. The breadth of mining and milling activities in the Grants Mineral Belt clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The present study provides a preliminary assessment of but a small facet of the overall

activity in the district. Further study is recommended to determine impacts of past operations or expected impacts from mines and mills now in the planning or construction stages. Site specific investigations are necessary to determine the hydraulic and water quality responses to dewatering and solution mining.

6. Additional ground-water samples should be collected from wells adjacent to the Rio Puerco and east of Gallup to determine if radium concentrations are acceptably low and to establish baseline conditions for future reference. It is recommended that concentrations of trace metals should also be measured.

AREAL DESCRIPTION

Location and Description of Study Area

The Grants Mineral Belt, located in the southeastern part of McKinley County and the north-central portion of Valencia County, is a rectangular shaped area in northwestern New Mexico (John and West, 1963). It is 24 to 32 kilometers wide in the north-south direction and 137 to 177 kilometers long from east to west (see Figure 1) (Kelley, 1963; Kittel, Kelley, and Melancon, 1967).

At present, three mining districts dominate the Mineral Belt. These are Churchrock on the west, Grants-Ambrosia Lake in the center, and Paguate-Jackpile on the east. These contain the Gallup, Churchrock, Smith Lake, Ambrosia Lake, Grants, North Laguna, and South Laguna mining areas. The districts are physiographically separated, Laguna lying to the east and Grants and Gallup to the west (Kelley, 1963; Kittel, Kelley, and Melancon, 1967).

The Continental Divide, extending through approximately the middle of the area, separates the region into two areas of drainage. West of the Divide, streams and rivers drain into the Gulf of California via the Colorado River system, while to the east they eventually join the Rio Grande (Dutton, 1885). Nearly all the streams in the area are intermittent and flow only during periods of intense precipitation (Cooper and John, 1968; Gordon, 1961).

The Grants Mineral Belt of northwestern New Mexico is within the Navajo and Datil sections of the Colorado Plateau physiographic province (Fenneman, 1931). To the east are the Southern Rocky Mountains and to the west and south, the Basin and Range province. To the north lie the Central Rocky Mountains.

Characteristic landforms within the study area include rugged mountains, broad, flat valleys, mesas, cuestas, rock terraces, steep escarpments, canyons, lava flows, volcanic cones, buttes, and arroyos (Kittel, Kelley, and Melancon, 1967; Cooper and John, 1968). Lava flows and volcanic necks are the predominant landmarks of the Datil section (Fenneman, 1931).

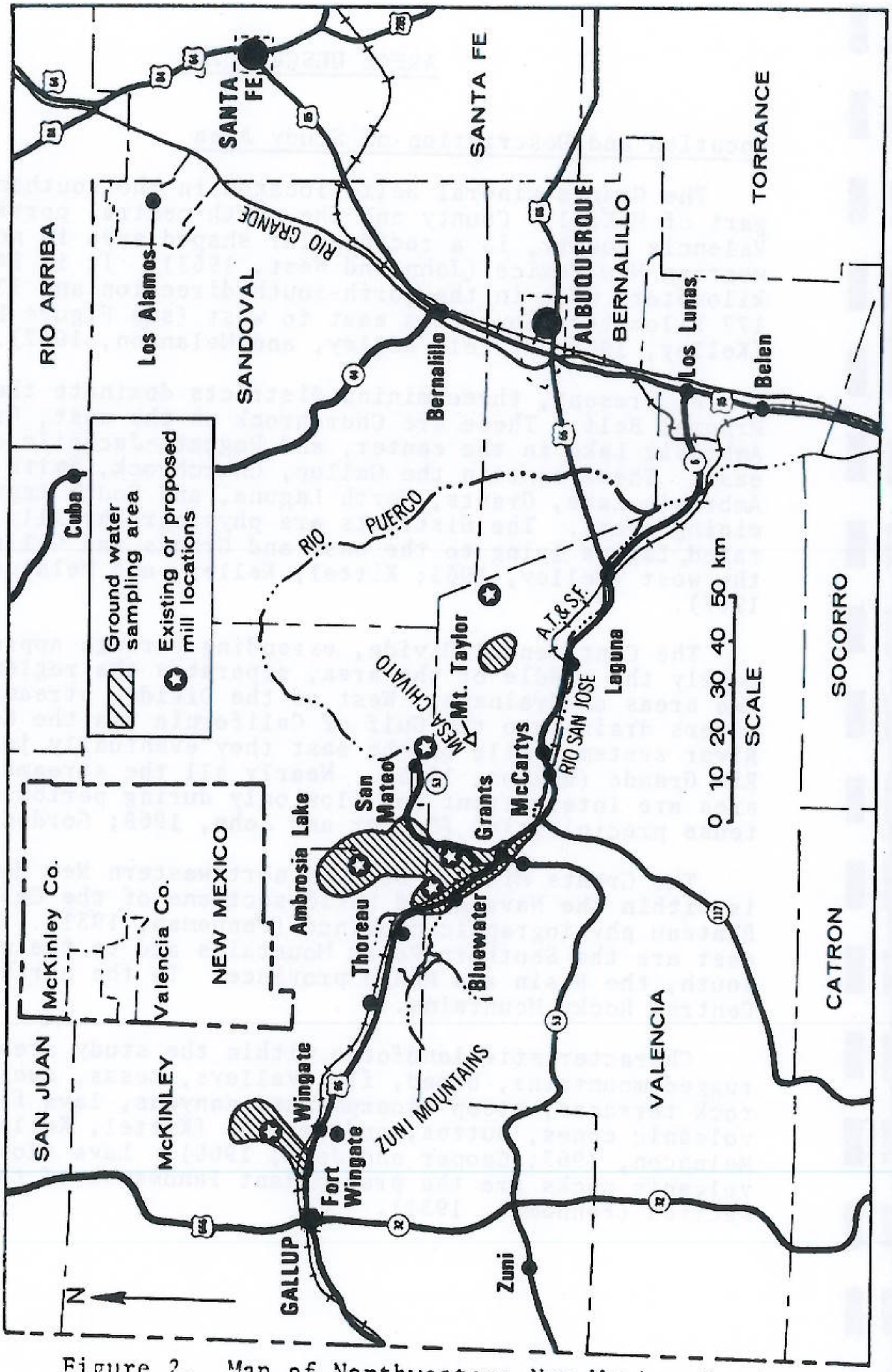


Figure 2. Map of Northwestern New Mexico Showing General Location of Sampling Areas in the Grants Mineral Belt

Prior to uranium mining and the discharge of mine and mill effluents, there were no perennial streams in southeastern McKinley County. In this period, the arroyos and wash channels and other natural depressions such as Ambrosia Lake, Casamero Lake and Smith Lake contained water only after heavy rains. There are intermittent ponds and lakes in the volcanic craters of the Cebolleta Mountains. The only perennial source of water is part of Bluewater Lake at the junction of Azul and Bluewater Creeks (Cooper and John, 1968).

Principal Industries

Until relatively recently, the principal industries in McKinley and Valencia Counties of northwestern New Mexico were farming and ranching. Tourism and small-scale logging were secondary. The land is mostly used for livestock grazing, while some irrigated farming is done in the valleys of Bluewater Creek and the Rio San Jose. The main crops are vegetables, and plants exist in the area for processing and packaging them.

Now that uranium ore has been found to be widespread throughout the Grants Mineral Belt, the uranium mining and milling industry predominates. What was a rural agricultural economy has partly become an industrial one. The figures on Table 1 indicate the importance of the uranium industry in the economy of New Mexico, especially the northwest part. The growth of the uranium industry has created a need for associated industries and services, especially the chemical industry. Caustic soda and soda ash are the main alkalies used in uranium milling. The construction and housing industries have flourished, and mining supply firms and concrete companies have been established (Gordon, 1961).

Gallup and Grants have grown rapidly, as have some of the smaller villages and communities. The population of McKinley County has grown from 27,451 in 1950 to 43,208 in 1970, and that of Valencia from 22,481 to 40,539 (University of New Mexico, Bureau of Business Research, 1972).

Table 1

Uranium Economy of New Mexico

Year	Production (tons or metric tons)	Value	Reserve	Percent of U. S. Total Reserve
1956	1,105,000 tons	$ 24,086,000	41 million tons	66 2/3%
1959	3,269,826 tons	$ 53,463,000	55 million tons	63%
Year ending June 30, 1962		McKinley Co. only $ 57,431,391		
1970	11,574,000 tons	$ 69,970,000		
1974	7,527 metric tons U_3O_8	$102,060,000		42%

1974 Production Capacity of Uranium Mills in New Mexico

Company	Plant Location		Nominal Capacity Tons Ore Per Day
The Anaconda Co.	Grants, New Mexico		3,000
Kerr-McGee Nuclear Corp.	Grants, New Mexico		7,000
United Nuclear-Homestake Partners	Grants, New Mexico		3,500
		Total	13,500
		Total U.S.	28,550
		Percentage in N.M.	47%

References: Midwest Research Institute (1975)
Health & Social Services, State of New Mexico (1975)
WASH 1174-74, The Nuclear Industry, USAEC (1974)

GEOLOGY AND HYDROLOGY

The principal bedrock and alluvial stratigraphic units in the Grants Mineral Belt range in age from Pennsylvanian to Recent (Hilpert, 1963). Figure 2, which is a generalized geologic cross section through the Grants and Ambrosia Lake areas, portrays these units and the dominant structural feature which is the Chaco slope developed on the north flank of the Zuni uplift. Conditions in the Churchrock area are essentially the same.

Pronounced topographic expression of the gently sloping bedrock units is abundantly evident in the Grants Mineral Belt. The sandstone strata on the mesas, actually gently dipping cuestas, form protective caps which resist weathering. The concave slopes and bottom lands form on less resistant units, typically shales and thin-bedded sandstones interbedded with shale. Although geographically less extensive, lava beds and limestone strata also function as caprocks.

Due to the scarcity of perennial surface water bodies, ground water is the principal source of water in the study area. Industrial, municipal, stock, and private domestic wells tap both bedrock and alluvial aquifers. In general, wells of low to moderate productivity are possible in the unconsolidated valley fill which constitutes an aquifer, primarily along the broad valleys of the Rio San Jose and the Rio Puerco. Numerous shallow domestic wells south and southwest of the United Nuclear-Homestake Partners mill also tap the shallow, unconfined aquifer. Part of the water supply for Gallup, and essentially all of that for Milan and Grants, is derived from shallow wells tapping valley fill and interbedded basalt layers (Dinwiddie et al., 1966).

Process water for the various uranium mills is derived from deep wells tapping bedrock aquifers. This is true for the Anaconda Company and United Nuclear-Homestake Partners mills, both of which tap the San Andres Limestone. Part of the feed water for the Kerr-McGee mill is from wells in the Morrison Formation and the more deeply buried Glorieta Sandstone and San Andres Limestone, with the balance coming from treated mine drainage water. Without exception, the operating mines continuously pump ground water as part of the mining operation. Where economical concentrations of uranium

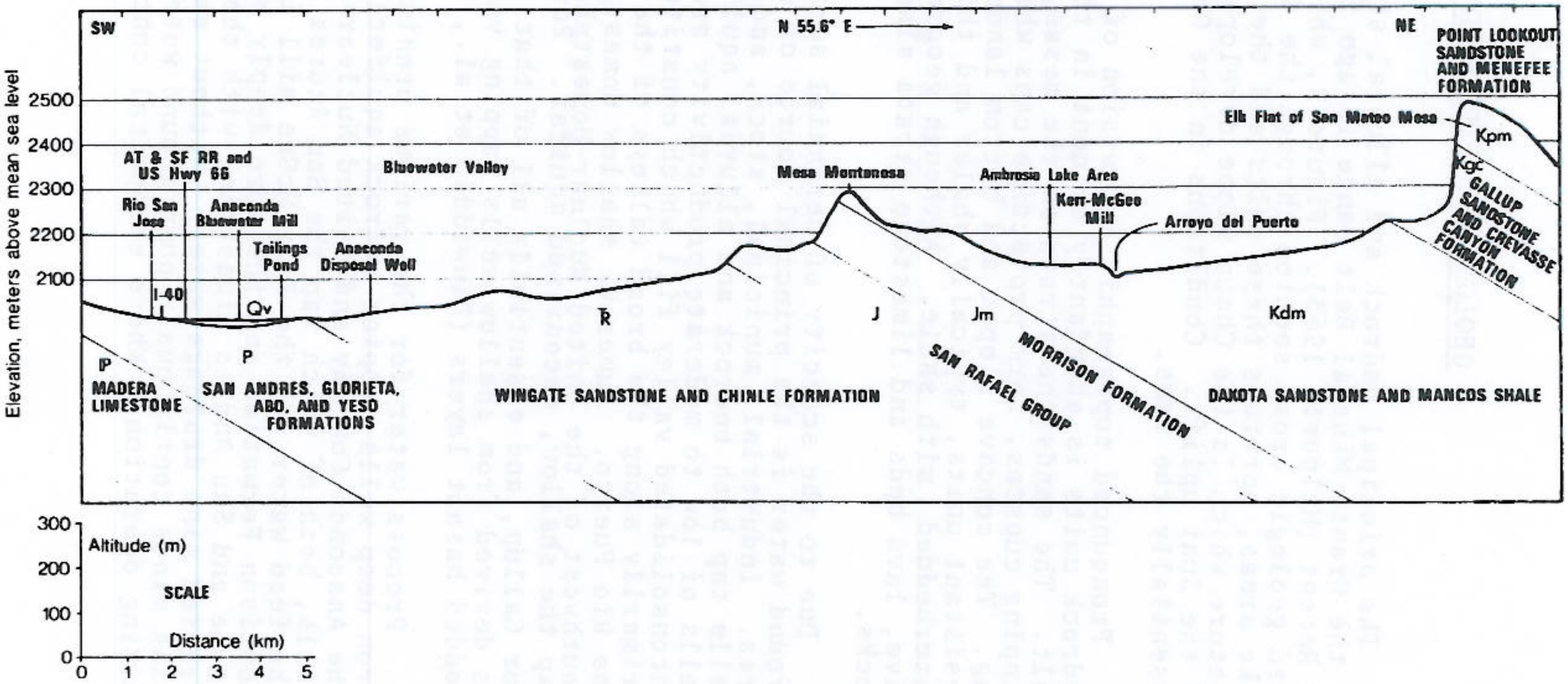


Figure 2, Generalized Structure Section from Bluewater to Ambrosia Lake are present, ion exchange plants are operated to effect recovery from the waste streams, but radium removal is not practiced. In effect, the various mines are high capacity wells which locally dewater the ore-bearing formations, chief of which is the Westwater Canyon Member of the Morrison Formation. To a lesser extent, the overlying strata such as the Dakota Formation are also affected by dewatering.

The impacts of ground-water pumping and discharge to surface water courses are varied. Declining water levels in the aquifers tapped, and possibly in the adjacent formations, are immediately noticeable. For example, in the Churchrock area, the static water level in the old Churchrock mine is declining about 0.3 meter per month due to dewatering at the United Nuclear and Kerr-McGee mines. Discharge of the mine water has transformed nearby dry washes and ephemeral streams into perennial ones. Rio Puerco, Arroyo del Puerto, and San Mateo Creek are cases in point. Water introduced to these channels will persist until the losses due to bed infiltration, evapotranspiration, and diversion equal inflow. Infiltration of such waters to shallow alluvial aquifers may be adverse, depending on the quality of infiltrating water relative to ambient water quality in the aquifer and the use to which shallow ground water is or will be put. The combination of declining water levels in the deeper, bedrock aquifers and deteriorated water quality in the shallow aquifers may have particularly adverse impacts on stock wells also used by the local populace for potable supply.

Sorption of radionuclides, such as radium on the stream sediments, may result in a buildup of material that will later be dispersed by channel scouring associated with flash flooding. Both the gradual buildup of radium in the sediments and its subsequent redistribution will result in increased levels of radioactivity in the environment as compared to ambient, pre-mining conditions.

Uranium mining and milling in the study area are of particular importance to several aquifers in the study area. Wastes from the Anaconda Company mill in Bluewater have infiltrated via the tailings pile and affected the shallow, unconfined aquifer (Tsivoglou and O'Connell, 1962). Injection of wastes into the deeply buried Abo and Yeso Formations has increased radioactivity and salinity levels therein. Strictly speaking, these are considered aquifers despite the mineralized water naturally present. Should the contamination move upward into potable aquifers and extend too far laterally, injection would likely be terminated. Widespread contamination of the shallow aquifer adjacent to the tailings pond would similarly require abatement.

The Chinle Formation is a source of domestic water in the Murray Acres and Broadview Acres subdivisions downgradient from the United Nuclear-Homestake Partners mill. As will be shown below, the shallow alluvial aquifer in this area is already believed to be contaminated by the infiltration of effluents from the mill.

In the Ambrosia Lake area, contamination of shallow ground water is likely to be a result of infiltration of 1) effluents from the tailings ponds at the Kerr-McGee mill, 2) mine drainage water that is introduced to settling lagoons and natural water courses, and 3) discharges from ion exchange plants. Seepage from the now inactive United Nuclear, Inc., (formerly Phillips) mill tailings pile is also undoubtedly present in the shallow subsurface. The ultimate impact of these waste waters on ground-water quality is unknown. It is unlikely that seepage returns to the deep, bedrock aquifers will occur because of their relatively great depth and the presence of numerous impermeable layers between the shallow alluvial materials and the principal aquifer (Westwater Canyon Member). A possible exception to this occurs in the vicinity of the Kerr-McGee Section 36 mine where drainage enters a nearby holding pond and seeps out the bottom at a rate of about 400 liters/minute. Seepage may move along the underlying San Mateo fault and enter potable aquifers. Very limited volumes of water in the shallow alluvium render it an insignificant source of supply. What water is present near the mining and milling areas is now likely to be contaminated to varying degrees by industrial effluents. The long-term infiltration of radium-laden water along the stream channel of San Mateo Creek, both above and below the confluence with Arroyo del Puerto, may adversely affect the quality of shallow ground water now developed for stock watering.

The potential for future problems of water availability for ore processing in Ambrosia Lake has been cited by Cooper and John (1968). In essence, dewatering of the principal aquifer (Westwater Canyon Member of the Morrison Formation) to facilitate mining may necessitate use of the poorer quality water in the underlying Bluff Sandstone.

Hydrogeologic conditions in the vicinity of the Churchrock mines basically resemble those in Ambrosia Lake with respect to potential impacts of mining and milling on ground water. The potential for contamination of shallow groundwater resources is greatest along the channel of the Rio Puerco. Under natural conditions, shallow ground water was scarce or nonexistent; hence, deeper wells completed in bedrock are required for a reliable supply. With continued infiltration of mine drainage water, at least local saturation of the alluvium may occur and lead to ground water development using shallow wells. However, the radium content of the drainage water discharged to date is excessive for potable or stock use of such water, and long term recharge with mine drainage water is not recommended. The potential for contamination of municipal wells along the Rio Puerco, particularly on the east and west fringes of Gallup, is unlikely.

INDUSTRY-SPONSORED WATER QUALITY MONITORING PROGRAMS

Introduction

A principal goal of the project was to evaluate the nature and extent of water monitoring programs, and data therefrom, as implemented by industry. This presumed that descriptions of the sampling points, analytical procedures, and resulting data would be available for examination upon request to the companies. With the exception of the Anaconda Company, this was not the case.

The inadequacies of industry-supported testing and monitoring programs noted by Clark (1974) include lack of sufficient data, intermittent data, and unreliable data.... conclusions, which are at least not contradicted by the present study.

The most extensive monitoring and testing programs to detect ground-water contamination are conducted by Kerr-McGee and Anaconda. By comparison, United Nuclear and United Nuclear-Homestake Partners have minimal programs both at the mines and at the mills. Therefore, the Kerr-McGee and Anaconda programs, although in need of revision, are a marked improvement compared to inactivity.

Of greatest environmental concern is the discharge of waste water originating from mining and from ore processing. Included in the latter is the discharge stream or tailings from conventional acid and alkaline leach mills and from ion-exchange plants. A third problem area, concerning impacts on ground-water quality from solution mining in the Ambrosia Lake area, is essentially unknown outside the industries involved.

Identification of industrial ground-water monitoring programs, if any, to determine hydraulic and water quality responses to both shaft and solution mining was beyond the scope of the present project. It is expected that solution mining and the use of IX plants, with and without recycling, will gain in popularity, particularly if stricter discharge limits for uranium induce greater capital investment in IX equipment. For this reason, and also because of the heavy ground-water extraction associated with deep mining, deliberate monitoring programs should be implemented and the data made publicly available to detect likely hydraulic and water quality responses.

Adequacy of Water Quality Data and Monitoring Programs

Evaluating the adequacy of a ground-water monitoring program is rather subjective and rarely will there be unanimity of opinion. The diversity of mining activities and geologic or hydrologic settings necessitates great variety in program design. Outlooks and goals of diverse groups also play a large role.

On the basis of the information utilized, the principal deficiencies with ongoing programs can be classified under the following headings:

1. Ground-water monitoring
2. Analytical techniques and reporting procedures
3. Regulatory agency review

Existing ground-water sampling networks range from non-existent to defective. The non-existent networks involve entire operations, as in the case of the United Nuclear Corporation, or portions of operations, as in the case of the solution mining conducted by United Nuclear-Homestake Partners.

The latter's monitoring of a single well at the mill site to determine shallow ground-water contamination is considered grossly deficient. In essentially every instance of mining and milling, baseline ground-water conditions were not defined. Therefore, any changes due to disruption of natural conditions cannot be assessed. In the case of the Anaconda waste management program, for example, there is no information concerning pre-disposal concentrations of stable and radioactive chemical species in overlying potable reservoirs already affected by the wastewater.

Of the active ground-water monitoring programs that were reviewed, great reliance is placed on documenting the quality of water in active wells within the surrounding region. This is laudable with respect to current water use, but not especially productive in terms of defining water quality impacts. In many instances, sampling wells are located hydraulically upgradient or are so far removed from the likely effects of mining or milling as to show no change. Wells of excessive depth, i.e., below the aquifer likely to show change, are also of dubious value as monitoring points. With the exception of a portion of the Kerr-McGee on-site net, wells specifically constructed for monitoring are commonly too few in number and improperly situated with respect to depth and (or) location. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment. There are indications that deterioration in water quality is occurring through time and very possibly in response to the waste volumes disposed of in the last 15 years. With regard to this disposal scheme, there is real question as to whether the data that have been generated have been scrutinized. In other instances, expected adverse impacts of seepage on shallow ground water have not been found because they have either not been sought or have been sought in unlikely locations.

No response to the requests for information regarding analytical methods and reported results was received from three of the four companies contacted. A review of the available records by the authors at the New Mexico Environmental Improvement Agency indicates many deficiencies in the company programs. These deficiencies include lack of information concerning minimum detectable activities for analytical procedures utilized, overly large error terms, poor agreement with outside laboratories, absence of quality assurance programs, inability to detect radionuclides at truly environmental or background levels, and irregular or random sampling frequencies. Analysis for specific radionuclides such as isotopic thorium, lead-210, polonium-210, radium-228, all of which are associated with mining and milling effluents, is rarely done. With the exception of the Anaconda Company, results of monitoring programs to determine background levels of both radionuclides or chemical components are not discussed in any of the reports of the companies. From the data/reports reviewed, it is doubtful that the various company laboratories have the analytical capabilities to accurately analyze for environmental levels of the common radionuclides associated with uranium mining and milling.

During February 11 and 12, 1975, a brief review of available company records, USAEC inspection reports, and mill licenses in the possession of NMEIA was conducted. The following findings are preliminary, as not all of the company records were available at the time of the review:

1. The available records are disorganized and incomplete. A complete copy of each company's radioactive material license and supporting correspondence could not be found. Radiological monitoring data reports were often missing or incomplete. Attachments and maps referred to in correspondence in the records could not be found.

2. Except for the license condition requiring monitoring data related to the Anaconda waste injection program, USAEC licenses for the other uranium mills have never specifically required the establishment of ground-water monitoring networks or reporting of any data pertaining to such monitoring. (Some limited programs have, however, been described in company license applications.)

3. It appears that no effort has been made to review or to summarize the reported monitoring data. No interpretive or summary reports concerning environmental impact have been prepared.

4. Almost no information has been reported by the companies describing their radiochemical analytical procedures, quality assurance programs, or the accuracy and precision of reported results.

5. Review by State and Federal regulatory agencies of reports of company efforts to evaluate the fate of liquid tailings waste effluents (e.g., materials and water balances between input versus evaporation, spillage, or ground seepage and total pond capacity) are essentially non-existent.

Noted deficiencies at the Federal level stem largely from the rather liberal, initial licensing conditions (with respect to ground-water monitoring), perfunctory inspection of company monitoring programs and data, and, in general, the somewhat haphazard manner in which information was filed and cataloged for later reference. Simply put, the uranium mining and milling industry has not been overly pressed to monitor and protect ground-water resources, and what efforts they have put forth have largely not been reviewed.

GROUND-WATER QUALITY IMPACTS

Introduction

The breadth of mining and milling operations in the study area clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The following discussion must necessarily be regarded as a preliminary assessment of but a small facet of the overall mining and milling activity. Impacts of inactive operations, such as the Phillips mill, or future impacts from sources under development, such as the Gulf mine and mill in San Mateo or the nearby Johnny M mine, are not addressed herein. Very large voids in our knowledge of impacts on water sources include solution mining practices and dewatering of ore bodies. Essentially no data or interpretive reports are available outside industry circles that describe the hydraulic and water quality impacts of these operations, which may well have the greatest impact of all on ground water.

Contaminated and background concentrations of selected radionuclides, as well as gross and trace chemical constituents, were determined for 71 wells in the study area. These data are presented in Tables 2 through 5. In certain locations, these data relate to surface water phenomena such as natural streams or to manmade features, foremost of which are tailings disposal ponds or streams originating as mine discharge.

The data are discussed by study area and by uranium mining/milling activities therein.

Table 5 summarizes ground-water data from the present study and categorizes the data according to study area and aquifer. These reported values are the lowest concentrations reported for samples collected during the study and may not necessarily represent "true" background or ambient values that may have existed prior to uranium mining and milling activities in this area. For the most part, the values shown for bedrock aquifers are not from the principal ore-producing formations, namely the Westwater Canyon Member of the Morrison Formation. In the Grants-Bluewater area, "bedrock" refers primarily to the San Andres Limestone, whereas near the United Nuclear-Homestake Partners mill, the term includes the San Andres Limestone and the Chinle Formation. At Ambrosia Lake, the Westwater Canyon Member and the Bluff Wingate Sandstones were sampled, whereas

Table 2
Sampling Point Locations and Gross Chemical Data for Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T	R	S	Q	LOCATION LAT.	LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	CONCENTRATION, mg/l TDS	CL	NH$_3$	NO$_2$ +NO$_3$ as N
Paguate-Jackpile																				
9230	Well #4 (Anaconda Co.)	11	5	27	421	350909	1072054	210.	34.9	2/75	3	2/28	PI	17.4	8.8	1100	540.	<0.2	0.05	0.05
9231	Well P-10 (Anaconda Co.)	10	5	4	413	350716	1072214	--	61.6	2/75	8	2/28	PI	36.1	8.3	2500	1200.	0.5	0.08	0.04
9232	New Shop Well (Anac. Co.)	10	5	9	224	350653	1072152	184.	--	--	3	2/28	PI	13.6	8.1	2500	1400.	0.5	0.14	0.05
9233	Paguate Municipal Well	11	5	32	241	350828	1072302	22.9	Art.	2/75	3	2/28	M	15.2	7.5	675	340.	6.6	0.08	0.20
Grants-Bluewater																				
9021	Injection Well (Anac.Co.)	12	10	8	314	351649	1075519	547.4	72.2	4/59	9	2/28	W					65.	69.0	32.8
9101	Mt. Taylor Mill Works Old Rt. 66	11	10	5	442	351224	1075422	58.5	--	--	1	2/24	PI	12.	6.25	1050	790.	25.	0.04	4.2
9103	C. Connerly	11	10	9	221	351212	1075331	37.2	24.4	2/75	3	2/25	P	12.	7.4	1200	880.	33.	<0.01	6.2
9111	C&E Concrete	11	10	22	341	350950	1075257	36.6	24.4	2/75	3	2/26	PI	14.	7.6	775	560.	30.	0.05	3.4
9112	Grants City Hall, Municipal water supply	11	10	26	244	350914	1075117	N/A	N/A	--	1	2/26	M	11.	7.3	1000	730.	32.	0.02	0.47
9115	Auro's Bar & Motel, Cowell House	12	11	24	334	351449	1075718	45.7	--	--	1	2/26	P	14.	7.1	1425	1100.	6.2	0.02	3.9
9116	Milan Well #1	11	10	21	221	351029	1075333	45.7	16.5	10/47	3	2/26	M	17.	7.5	700	500.	14.	0.02	1.6
9117	Monitor Well (Anac. Co.)	12	10	8	332	351650	1075518	191.4	58.3	3/60	1	2/27	O	20.	6.8	2900	2300.	11.	0.03	1.5
9118	Well #2 (Anac. Co.)	12	11	24	234	351527	1075648	118.	51.2	5/72	3	2/27	IP	18.5	7.1	2550	1900.	270.	0.64	39.9
9119	Well #4 (Anac. Co.)	12	11	25	214	351436	1075650	69.	42.1	5/72	3	2/27	IP	17.	7.2	1225	890.	42.	0.13	5.7
9120	Mexican Camp	12	10	30	112	351443	1075617	85.3	43.6	2/47	3	2/27	O	15.	7.5	720	490.	10.	0.04	0.73
9121	Berryhill, Sec. 5 (Anac. Co.)	12	10	5	341	351813	1075512	221.	74.9	1/58	4	2/27	S	20.	7.0	2900	2000.	4.2	0.14	0.35
9122	North Well (Anac. Co.)	12	10	7	143	351731	1075611	76.2	53.9	10/55	4	2/27	O	17.5	7.4	2200	1900.	4.2	0.08	1.3
9123	Engineer's Well	12	11	14	213	351643	1075801	35.1	26.8	2/75	2	2/28	O	11.5	7.3	1625	950.	61.	0.09	3.2
9124	Berryhill House	12	11	11	334	351659	1075823	45.7	37.1	6/56	1	2/28	P	11.	7.5	1800	940.	65.	0.05	0.8
9125	LDS Church-Bluewater	12	11	22	234	351521	1075859	79.2	27.9	12/46	1	2/28	M	5.	7.5	1800	1000.	12.	0.05	0.95
9126	Roundy House Well	12	11	23	231	351532	1075900	91.4	21.2	1/47	1	2/28	P	10.5	7.3	1975	1100.	110.	0.04	6.5
9127	Fred Freas	12	10	30	433	351347	1075552	41.1	--	--	3	2/28	P	13.	7.7	1025	540.	13.	0.03	0.03
9128	Leroy Chapman	12	10	32	211	351338	1075450	41.1	23.	1/47	1	2/28	P	11.	7.6	950	490.	13.	0.03	1.4
9129	Jack Freas	12	10	30	242	351424	1075530	48.8	32.5	2/55	1	2/28	P	11.5	7.5	1325	790.	54.	0.04	2.5

(Continued)

(continued)
Table 2
Sampling Point Locations and Gross Chemical Data for
Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T	R	S	Q	LOCATION LAT.	LOCATION LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	CONCENTRATION, mg/l TDS	CL	NH_3	NO_2 $+NO_3$ as N
United Nuclear-Homestake Partners																				
9102	G. Wilcox	12	10	27	442	351410	1075217	32.6	--	--	3	2/24	P	14.	6.5	2850	2300.	130.	0.01	5.5
9104	T. Simpson	12	10	27	444	351403	1075217	87.5	--		1	2/25	P	10.	8.4	2050	1400.	37.	<0.01	0.08
9105	Schwagerty	12	10	34	224	351351	1075218	77.7	--		1	2/25	P	11.	7.5	1950	1300.	46.	<0.01	1.00
9106	J. Pitman	12	10	35	332	351345	1075214	89.9	--		1	2/25	P	14.	8.8	1725	1300.	39.	<0.01	0.23
9107	C. Worthen	12	10	35	332	351341	1075208	26.2	5.5	2/75	3	2/25	P	14.	7.4	4000	3800.	260.	0.01	62
9108	Pitney	12	10	27	431	351406	1075246	54.9	--	--	6	2/25	P	14.	7.6	2775	2200.	110.	0.01	3.3
9109	T. A. Chapman	12	10	34	121	351352	1075255	38.1	13.1	2/75	6	2/25	P	14.5	7.5	1700	1300.	9.5	0.01	2.5
9113	C. Meador	12	10	35	144	351336	1075150	36.6	--		1	2/26	P	8.	7.8	2025	1600.	120.	0.01	2.9
9114	Bell	12	10	25	133	351427	1075108	152.4	--		1	2/26	P	17.	8.3	1475	970.	34.	<0.01	0.00
9133	G. Enyart	12	10	27	331	351408	1075312	64.0	15.2	3/75	1	3/02	P	18.	7.6	3000	1600.	50.	0.26	0.97
9134	Well #2 (UNHP)	12	10	26	311	351422	1075146	121.9	21.6	5/56	3	3/03	PI	15.	6.95	1600	1600.	0.2	0.03	0.42
9135	Well D (UNHP)	12	10	26	313	351417	1075208	26.8	16.4	3/75	3	3/03	O	12.	7.2	3500	4500.	340.	1.0	2.6
9136	Well #1 (UNHP)	12	10	26	242	351431	1075117	298.7	40.8	5/58	3	3/03	PI	18.	6.9	1850	2000.	<0.2	0.07	0.28
Ambrosia Lake																				
9130	N. Marquez house well	13	9	23	212	352048	1074527	25.3	15.4	3/75	3	3/01	N	16.	8.9	1300	720.	4.8	0.04	0.06
9131	C. Sandoval windmill	13	9	22	212	352043	1074526	39.6	11.2	2/75	3	3/01	S	14.	8.0	1300	660.	27.	0.06	1.2
9132	N. Marquez windmill	13	9	21	414	352022	1074803	44.2	19.5	3/75	5	3/01	N	14.	7.6	4250	2200.	43.	0.22	106.3
9201	KM-46, P. Harris (Wilcoxson)	13	9	16	411	352114	1074738	76.2	--	--	3	2/26	PS	13.	6.7	3250	1900.	23.	0.14	0.09
9202	KM-52, County Lne Stk Tnk	12	10	12	433	351636	1075037	30.5	14.2	11/55	3	2/26	SP	6.5	7.05	2200	2100.	56.	0.06	62
9203	KM-45, Navajo windmill	13	10	8	211	352233	1075508	108.8	--	--	7	2/26	SP	3.1	8.5	620	400.	6.8	0.02	4.0
9204	KM-49, Ingersoll Pand	13	9	22	121	352050	1074655	90.5	--	--	1	2/26	P	6.4	7.45	2150	2200.	36.	0.05	79.7
9205	KM-47, Bingham	13	9	22	121	352053	1074650	79.2	--	--	3	2/26	P	14.2	7.1	3100	2000.	40.	0.04	4.7
9206	KM-63, Marquez	13	9	15	343	352055	1074647	117.3	--	--	3	2/26	P	13.	7.15	2050	1900.	34.	0.05	4.4
9207	KM-S-12	14	9	32	313	352346	1074911	12.5	0.91	2/75	5	2/27	O	11.9	6.5	>8000	14000.	3100.	0.50	0.94
9208	KM-43	14	9	32	321	352355	1074900	16.2	6.4	2/75	5	2/27	O	13.	7.5	7000	7800.	2.8	NS	NS
9209	KM-44	14	9	32	312	352355	1074902	42.1	32.9	2/75	5	2/27	O	14.1	7.1	3100	2700.	17.	0.66	48.7
9210	KM-51	14	9	32	322	352353	1074850	19.2	8.8	2/75	2	2/27	O	11.9	7.0	6000	6300.	44.	0.30	350
9211	KM-48	14	9	30	432	352430	1074939	16.2	11.3	2/75	5	2/27	O	13.	7.0	4200	4100.	31.	[illegible]	1.3
9212	KM, Seepage return	14	9	31	442	352342	1074919	N/A	N/A	N/A	3	3/03	-	9.	2.2	>>8000	36000.	3100.	590.	53
9213	KM-B-2	14	9	31	421	352354	1074926	8.2	1.04	3/75	5	3/03	O	8.6	5.5	>>8000	8900.	3400.	0.12	0.25

(Continued)

(continued)
Table 2
Sampling Point Locations and Gross Chemical Data for
Ground-water Samples from the Grants Mineral Belt, New Mexico

NUMBER	DESCRIPTION	T R S Q	LOCATION LAT.	LONG.	WELL DEPTH (m)	STATIC WATER LEVEL (m)	DATE MEAS.	SAMPLE POINT TYPE[1]	DATE SAMPLED[2]	WATER USE[3]	TEMP. °C	pH	SP. COND. umhos/cm	TDS	CONCENTRATION, mg/l CL	NH$_3$	NO$_2$ +NO$_3$ as N
Ambrosia Lake (Continued)																	
9214	KM-36-2	14 10 36 422	352352	1075026	17.4	10.1	3/75	5	3/03	0	12.5	6.85	>8000	9100.	1700.	2.9	8.0
9215	KM-46	14 9 30 331	352430	1075017	11.6	10.1	2/75	2	3/03	0	13.	6.7	3250	3200.	100.	10.	2.0
9216	KM-47	14 9 30 341	352430	1074959	18.9	7.3	2/75	5	3/03	0	14.2	7.1	3100	2600.	74.	0.80	2.6
9217	KM-50	14 9 32 114	352414	1074901	16.6	14.0	2/75	2	3/03	0	11.9	7.7	5750	4700.	470.	9.1	70.9
9218	KM-5-1	13 9 5 214	352316	1074835	10.4	7.3	3/75	5	3/03	0	13.5	6.95	5000	4800.	61.	0.16	0.40
9219	KM-5-2	13 9 5 141	352310	1074856	10.4	6.0	3/75	5	3/03	0	12.5	7.1	>8000	6700.	1300.	0.08	1.3
Gallup-Churchrock																	
9137	Erwin well	16 18 7 433	353730	1084524	610.	221.0	3/75	3	3/05	M	--	7.85	1225	740.	14.	0.09	0.02
9138	Boardman Trailer Park	15 18 14 243	353159	1084237	91.4	45.7	3/75	3	3/05	P	--	7.6	1450	930.	<0.2	0.50	1.2
9139	G. Hassler	15 17 8 133	353242	1084008	91.4	4.6	3/75	1	3/05	P	--	7.75	1400	880.	98.	0.02	119.6
9140	Dixie well	15 17 9 413	353227	1083835	--	1.2	3/75	3	3/05	N	--	7.7	2400	1500.	<0.2	0.30	0.16
9141	Churchrock Village	15 17 12 333	353222	1083553	65.6	--	--	6	3/05	P	--	7.8	1375	720.	0.5	0.50	0.18
9142	White well	16 16 16 422	353701	1083147	--	2.1	3/75	2	3/05	N	--	8.00	1000	620.	630.	0.01	0.02
9220	CRKM-2, Hardground Flats well	Navajo Reservation	353958	1083404	189.6	--	--	4	3/05	SP	--	9.15	1350	850.	0.	0.03	0.28
9221	CRKM-11, E. Puerco River well (=Togay well, 9143)	16 16 15 431	353638	1083059	96.9	--	--	7	3/05	SP	--	7.65	550	340.	14.	0.04	62
9222	CRKM-16, Puerco well	16 17 25 113	353533	1083551	42.7	7.04	3/75	7	3/05	SP	--	7.25	2200	1600.	0.	34.	0.01
9223	CRKM-5, Pipeline Rd well	16 15 33 422	353420	1083810	37.2	10.7	3/75	7	3/05	S	--	7.65	1350	880.	0.	1.4	1.6
9224	CRKM-3, Nose Rock well	16 17 15 131	353709	1083720	207.3	31.4	--	4	3/05	SP	--	8.9	1550	980.	0.	0.07	0.03
9225	CRKM-10, N.E. Pipeline well	Navajo Reservation	354015	1082841	284.1	>91.4	3/75	7	3/05	SP	--	8.05	2650	2300.	8.1	0.12	0.01

Explanation

1 - Sampling Point
1-outside faucet
2-hand bailed
3-pumped (well head)
4-windmill
5-mobile pump
6-kitchen faucet
7-holding tank
8-wash room
9-pre-injection filter discharge

2 - Date Sampled
1975

3 - Well Type
N-not in use
P-potable
S-stock
M-municipal supply
I-industrial
0-observation/monitor
W-waste discharge

Table 3
Selenium and Vanadium Concentrations in Selected Ground-water Samples[1]

NUMBER	DESCRIPTION	Se (mg/l)	V (mg/l)
United Nuclear-Homestake Partners			
9102	G. Wilcox	1.06	<0.3
9107	C. Worthen	1.06	0.3
9113	C. Meador	0.20	0.3
9134	Well #2 (UNHP)	<0.01	1.3
9135	Well D (UHNP)	1.52	0.4
Grants Bluewater			
9117	Monitor well (Anaconda)	0.01	0.3
9118	Well #2	0.01	0.8
9119	Well #4	<0.01	0.9
9120	Mexican Camp	<0.01	1.0
9121	Berryhill, Section 5	<0.01	0.8
9123	Engineer's well	0.01	1.1
9129	Jack Freas	0.02	1.3
Ambrosia Lake			
9132	N. Marquez windmill	.13	< .3
9201	KM-46, P. Harris (Wilcoxson)	<0.01	< .3
9207	KM-S-12	<0.01	0.4
9208	KM-43	.29	0.8
9209	KM-44	.01	<0.3
9211	KM-48	<0.1	0.5
9213	KM-B-2	<0.1	0.6
9214	KM-36-2	.02	<0.3
9215	KM-46	<0.01	<0.3
9219	KM-5-2	0.01	<0.3
Gallup-Churchrock			
9138	Boardman Trailer Park	<0.01	<0.3
9140	Dixie well	<0.01	<0.3
9141	Churchrock Village	<0.01	<0.3
9142	White well	<0.01	<0.3
9221	CRKM-11, E. Puerco	0.01	<0.3
9222	CRKM-16, Puerco well	<0.01	<0.3
Paguate-Jackpile			
9230	Well #4	<0.01	<0.3
9232	New Shop well	<0.01	<0.3
9233	Paguate Municipal well	0.01	<0.3

[1] Analyzed by National Enforcement Investigations Center, Denver, Colorado.

Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Number	Location Description	Gross Alpha	Ra-226 NEIC	Ra-226 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
	Paquate-Jackpile											
9230	Well #4	< 2.0 ± 5	0.31 ± .02	0.23 ±.095						< 0.029	0.012	0.31 ± .11
9231	Well P-10	10 ± 10	1.7 ± .03							< 0.016	< 0.016	0.29 ± .11
9232	New Shop Well	18 ± 13	3.7 ± .03					0.02	14	< 0.016	< 0.011	0.69 ± .20
9233	Paquate Municipal Well	2 ± 4	0.13 ± .02	0.10 ±.072				0.04	27	< 0.018	< 0.010	0.39 ± .18
	Grants--Bluewater Area											
9021	Injection well	62,500±1,300	53 ±1	27 ±0.95	10,000±750	420 ±67	11,000±770	130	86,00	82000±1200	51 ± 30	3,100±250
	Anaconda Company											
9101	Mt. Taylor Mill Works	9± 11	0.13± .01									
	Old Rt. 66											
9103	Q. Connerly	7± 10	0.09± .01									
9111	C&E Concrete	7± 9	0.24± .01							<0.028	<0.012	0.55± .15
9112	Grants City Hall	19± 13	0.42± .02	0.10± .098						0.046±.038	0.0094±.021	0.26± .14
9115	Cowell House	7± 12	0.18± .01									
9116	Milan well No. 1	12± 10	0.14± .01							<0.0072	<0.013	0.30± .12
9117	Monitor well	180± 40	2.6 ± .1	2.6 ± .30	100± 7.7	3.0± .58	74± 5.7	0.56	579	<0.016	<0.0097	2.3 ± .95
	Anaconda Company											
9118	well No. 2	290± 50	0.50± .02	0.21± .09				1.3	36	0.52±.093	0.54±.094	1.1 ± .37
	Anaconda Company											
9119	well No. 4	12± 11	0.20± .01	0.19± .089						<0.030	<0.019	0.26± .13
	Anaconda Company											
9120	Mexican Camp	21± 12	0.27± .02							<0.017	<0.0053	0.66± .25
9121	Berryhill Section 5	12± 14	6.3 ± .1							<0.0081	<0.0031	0.28± .17
9122	North well	30± 17	0.17± .01							0.034±.024	<0.0084	0.51± .17
9123	Engineer's well	20± 13	0.26± .01	0.36± .11						0.033±.026	<0.018	0.46± .20
9124	Berryhill House	16± 12	0.06± .01									
9125	LDS Church--Bluewater	3± 10	0.22± .01							<0.034	<0.012	<0.070
9126	Roundy House	5± 9	0.11± .01							0.040±.031	<0.015	<0.10
9127	Fred Freas	10± 10	0.21± .01	0.28± .11						<0.034	<0.029	0.39± .14
9128	L. Chapman	11± 11	0.15± .01									
9129	Jack Freas	<1.6± 7	0.14± .01	0.87± .29						<0.018	<0.012	0.31± .16

(continued)
Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Number	Location Description	Gross Alpha	Ra-226 NEIC	Ra-226 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
	United Nuclear - Homestake Partners											
9102-J.	Wilcox	< 3 ± 13	0.19 ± .01	0.22±.091	10 ± .73	0.22± .048	7.7 ± .57	0.07	47	<0.021	<0.012	1.0 ± .95
9104-T.	Simpson	13 ± 14	0.08 ± .01							0.048±.029	<0.021	0.31± .14
9105-	Schwagerty	140 ± 30	0.05 ± .01									
9106-J.	Pitman	12 ± 11	0.05 ± .01	0.19±.087						<0.017	<0.010	0.40± .26
9107-C.	Worthen	2500 ±200	0.72 ± .02	0.78±.17				14	9478	0.99 ±.13	0.034±0.031	1.2 ± .52
9108	Pitney	47 ± 23	0.34 ± .02							0.026±.023	<0.013	0.31± .14
9109-T.	A. Chapman	39 ± 17	0.13 ± .01									
9113-C.	Meador	31 ± 17	0.17 ± .02	<0.072				0.08	54	<0.037	<0.042	2.3 ± .69
9114	Bell	42 ± 18	0.26 ± .01									
9133-G.	Enyart	10 ± 12	0.61 ± .03	0.65±.15	5.1±.41	0.15± .04	3.8 ± .31			0.36 ±.078	<0.016	0.95± .24
9134-	Well #2 UNHP	8 ± 11	0.24 ± .01					0.04	27	0.045±.039	<0.026	0.76± .41
9135-	Well D UNHP	400 ± 70	1.92 ± .04	2.3 ±.31	240±16	9.3 ±1.1	240 ±16	2.6	1760	<0.013	<0.013	2.3 ±2.1
9136-	Well #1 UNHP	22 ± 16	0.27 ± .02									
	Ambrosia Lake											
9130	N. Marquez House	3± 6	0.11 ± .01									
9131	C. Sandoval Windmill	18± 13	0.05 ± .01	0.22 ± .10						0.036±.025	< 0.021	< 0.55
9132	N. Marquez Windmill	< 1.0± 9	0.31 ± .02	0.47 ± .14	81 ± 5.1	2.6 ± .25	74 ±4.7	0.10	68	<0.015	< 0.012	0.79 ±0.43
9201	P. Harris	110± 40	3.6 ± .1					1.0	677	0.03 ±.027	< 0.014	0.52 ±0.16
9202	County Line Stock Tank	86± 51	0.30 ± .02							<0.028	< 0.011	0.22 ±0.10
9203	Navajo Windmill	55± 15	0.07 ± .01									
9204	Ingersoll Ranch	8± 13	0.14 ± .01	0.50 ± .11						<0.015	< 0.017	0.61 ±0.21
9205	Bingham; KM-47	170± 40	0.18 ± .01									
9206	Marquez; KM-65	56± 25	0.60 ± .02									
9207	KM-S-12	410± 120	1.15 ± .03							0.27 ±.066	0.28±.062	< 0.16
9208	KM-43	49± 55	4.0 ± .1	4.7 ± .40						0.021±.013	< 0.014	< 2.[illegible]
9209	KM-44	< 2.0± 10	1.95 ± .04							<0.026	< 0.022	0.6[illegible] ±0.33
9210	KM-51	45± 29	0.26 ± .02	0.35 ± .12						<0.023	< 0.0068	0.24 ±0.1[illegible]
9211	KM-48	< 3.0± 15	0.20 ± .01							<0.013	< 0.0040	2.7 ±0.[illegible]
9212	KM-Seepage Return	112,000±3,000	4.9 ± .1	10.[illegible] ± .[illegible]								
9213	KM-S-2	8± 32	6.6 ± .1	6.4 ± .47						<0.01[illegible]	< 0.011	< 0.64
9214	KM-36-2	14± 34	1.12 ± .03	1.5 ± .23	11 ± .76	0.31±.056	6.8 ± .5[illegible]			<0.015	< 0.014	0.70 ±0.2[illegible]

(continued)

(continued)
Table 4

Radiological Data for Selected Ground-water Samples[1]

Grants Mineral Belt, New Mexico

Location Number Description	Gross Alpha	Ra-226 NEIC	 EMSL	U-234	U-235	U-238	U-nat.		Th-230	Th-232	Po-210
Ambrosia Lake (Continued)											
9215 KM-4c	104± 37	2.5 ± .2	2.7 ± .30						0.17 ±.057	< 0.016	< [illegible]
9216 KM-47	45± 25	0.64 ± .02							0.079±.036	< 0.017	0.29 ±[illegible]
9217 KM-[illegible]	70± 38	0.94 ± .03	0.72 ± .16						0.055±.035	< 0.015	1.2 ±0.64
9218 KM-5-1	20± 24	0.34 ± .02	0.34 ± .11						<0.021	< 0.016	3.9 ±2.6
9219 KM-5-2	67± 42	0.59 ± .02	0.76 ± .17	12 ± .63	0.27± .039	6.7 ± .37			<0.039	< 0.031	0.96 ±0.64
Gallup-Churchrock											
9137-Irwin Well	10 ± 9	0.63 ± .03									
9138-Boardman Trailer Park	6 ± 8	0.64 ± .02							0.088±.038	< 0.019	0.27± .20
9139-G. Hassler	14 ± 11	0.22 ± .01									
9140-Dixie Well	6 ± 10	0.10 ± .01	0.15 ± .032	1.8 ± .16	0.053±.022	1.4 ± .14			<0.030	< 0.016	0.50± .20
9141-Churchrock Village	3 ± 7	0.12 ± .01	0.26 ± .10				0.02	14	<0.028	< 0.016	0.23± .11
9142-White Well	9 ± 9	0.16 ± .01	0.42 ± .13						0.073±.035	< 0.011	<0.083
9143-Togay Well(same as 9221)	14 ± 9	0.83 ± .04	0.38 ± .12						<0.044	< 0.034	0.42± .17
9220-Hardground Flats Well-CRKM-2	12 ± 10	0.12 ± .01									
9221-E.Puerco River Well-CRKM-11	17 ± 10	0.56 ± .02	0.21 ± .093						<0.029	< 0.016	0.19± .13
9222-Puerco Well CRKM-15	2 ± 9	0.57 ± .02									
9223-Pipeline Road Well-CRKM-5	4 ± 9	0.37 ± .02							0.037±.023	< 0.012	0.52± .15
9224-Rose Rock Well CRKM-3	24 ± 12	0.13 ± .01							0.053±.043	< 0.036	0.23± .13
9225-N.E. Pipeline Well CRKM-10	12 ± 15	0.29 ± .01							<0.015	< 0.011	0.56± .35

1. Concentrations ± two sigma counting error in pCi/l . U-natural reported as mg/l and in pCi/l, respectively.

Sources of analyses:
Environmental Monitoring and Support Laboratory, USEPA: Ra-226, U-234, U-235, U-238, Th-230, Th-232, Po-210, Pb-210
National Enforcement Investigations Center, USEPA: Gross alpha, Ra-226, U-nat.

All analyses except U-nat. are on the filtered sample and therefore represent the concentrations actually in solution.
U-nat. is analyzed using unfiltered water and represents both the dissolved and suspended fractions.

Table 5

Typical Background Ground Water Radionuclide Concentrations (pCi/l) by Geographic Area & Aquifer [1]

Radionuclide/Aquifer		Paguate-Jackpile	Grants-Bluewater	MHP	Ambrosia Lake	Gallup-Churchrock
^{226}Ra	Bedrock	0.31 ± .02	0.14 ± .01	0.36 ± .01	0.16 ± .01	0.12 ± .01
	Alluvium	<0.13[3]	0.13 ± .01	0.15 ± .02	0.23 ± .02	0.11 ± .01
^{210}Po	Bedrock	0.43 ± .14	0.33 ± .15	0.35 ± .20[2]	0.57 ± .19	0.35 ± .19
	Alluvium	<0.39[3]	0.30 ± .14	<0.31[3]	0.27 ± .18	0.27 ± .17
^{230}Th	Bedrock	<0.020	<0.032	<0.033	<0.023	<0.035
	Alluvium	<0.018[3]	<0.013	<0.014	<0.028	<0.061
^{232}Th	Bedrock	<0.013	<0.015	<0.015	<0.013	<0.024
	Alluvium	<0.013[3]	<0.013	<0.013	<0.018	<0.015
^{234}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<10[3]	<12	<1.3[3]
^{235}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<0.23[3]	<0.29	<0.053[3]
^{238}U	Bedrock	---	---	---	---	---
	Alluvium	---	---	<7.7[3]	<5.3	<1.4[3]
U-Natural						
	Bedrock	14[3]	---	---	---	---
	Alluvium	27[3]	---	54	68[3]	14[3]

---

(1) Average of lowest reported concentrations of this study. ^{226}Ra and U-natural analyses by [illegible], all other radionuclide analyses by [illegible].

[2] Based on Chinle Formation.

[3] Results of only one sample reported: therefore, two sigma error of 100% assumed for these values.

bedrock aquifers in the Churchrock mining area mostly include the Dakota Sandstone. In the Paguate-Jackpile area, three of the four wells examined are in the Morrison Formation (Jackpile Sandstone Member).

Table 6 is a compilation of uranium, radium, and gross

Table 6 is a compilation of uranium, radium, and gross beta concentrations in ground water for various localities in the Grants Mineral Belt. These are largely from the ore bodies or from strata adjacent thereto, and are intended to show natural concentrations of these radionuclides. Despite the wide variations, radium rarely exceeds 10 pCi/1 and is commonly less than 5 pCi/1, except in mines or in ponds formed from mine drainage. Dissolved uranium is also enriched in waters associated with active mines and can readily reach concentrations of several hundred pCi/1. Natural background uranium levels are difficult to estimate from the limited data but would appear to be on the order of 20 pCi/1 or less. Concentrations markedly greater than the foregoing, particularly if associated with mining and milling activity, may be evidence of degradation.

Bluewater-Milan-Grants

The relationship of the Anaconda Company mill and tailings pile to local geologic and cultural features is shown in Figure 3. Cultivated areas in the photograph are situated in Bluewater Valley which contains the town of Bluewater on the western edge. The irregularly shaped landforms northeast and east of the mill are basalt lava flows which are also the substrate for a portion of the tailings ponds. Also shown is the proximity of the San Andres Limestone to the tailings ponds. The light colored areas in the tailings pond are composed of sand, whereas the darker gray and black patterns indicate wet slimes and free water surface, respectively.

The expected impacts of uranium mining and milling on groundwater in the developed area between Bluewater and Grants can be traced to the Anaconda Company mill. It is unlikely that the United Nuclear-Homestake Partners mill could adversely affect ground water in this area.

Significant introduction of wastes into ground water in the Bluewater area occurs as a result of seepage from the tailings ponds. Past investigators noted the migration of nitrate from the ponds (New Mexico Department of Public Health, 1957). Changes in the milling process greatly

Table 6

Summary of Reported Concentrations for Radium, Gross Beta and Natural Uranium in Ground Water in the Grants Mineral Belt[1]

Location T R S Q	Source	Depth (meters)	Aquifer[2]	Radium pCi/l	gross β pCi/l	U natural dissolved pCi/l
9 12 11 222	Paxton Spring	Spring	Qb	4.3		1.82
12 11 24 4	Industrial Well	109		0.4		4.27
12 11 24 4	Anaconda Well (Injection)	109	Ps	0.36		
12 12 4 343	Bluewater Lake	Surface		<0.1		0.84
12 10 8 3	Well	442	Pym	0.2±0.1		1.96
13 8 30 100	El Paso Natural Gas Co.		Jmw	8.5±1.7	36 ± 5	
13 8 30 200	El Paso Natural Gas Co.		Kd	2.9±0.6	12 ± 2	
13 9 29 144	Westvaco Mineral Development Co.		Jt	5.1	150	
13 9 29 41	Mine Drift	137	Jt	5.1		139
14 9 28 441	Well		Jmw	1.1		<.07
14 9 32 413	Well	174	Jmw	10 ±2		8.4
14 9 32 221	Mine Drift		Jmw	42		16.1
14 9 17 400	Kermac Nuclear Fuels Corp.		Kd	2.7±0.5	18 ± 3	
14 9 18 400	Kermac Nuclear Fuels Corp.		Jmw	5.6±1.1	37 ± 6	
14 9 28 143	Kermac Nuclear Fuels Corp.	216	Jmw	1.1	69	
14 9 29 312	Phillips Petroleum Co.	224	Jmw	10 ±2	39 ± 7	
14 9 30 200	Kermac Nuclear Fuels Corp.		Jmw	2.0±0.4	12 ± 2	
14 9 32 122	Homestake-New Mexico Partners	196	Jmw	42	49	
14 9 32 314	Homestake-New Mexico Partners	168	Jmw	1.1±0.2	18 ± 4	
14 9 34 422	United Nuclear Company	306	Jmw	1.4±0.3	9.0± 1.3	
14 9 36 313	United Nuclear Company		Kd	27 ±5	75 ±11	
14 9 36 313	United Nuclear Company	457	Jmw	1.2±0.2	6.5± 0.9	
14 10 24 100	Kermac Nuclear Fuels Corp.		Jmw	2.3±0.5	56 ± 8	
15 12 17 123	Homestake-Sapin Partner	372	Jmw	0.2±0.1	9.5± 1.4	
17 12 20 11	Crownpoint Well 1	714	Jmw	0.05		<0.28
17 16 35 14	UNC-NE Churchrock Mine	457	Jmw	0.62		185
17 16 35 14	UNC-NE Churchrock Mine	518	Jmw	0.09		22
17 16 35 14	UNC-NE Churchrock Mine	549	Jmw	8.10		847
17 16 35 12	KM-Section 35, Churchrock Mine	549	Jmw			
23 14 3 13	Gas Company Burnham Well 1	1585	Jmw	0.24		0.05
	Pond in South Paguate pit	Pond		190		170

1. Data sources are as follows:

Ambrosia Lake area:	Cooper and John, 1968
Laguna-Paguate:	Lyford, 1975
Churchrock:	Hiss and Kelley, 1975
Grants-Bluewater- : Prewitt	Stow, 1961

Grants-Bluewater-Prewitt:

2. Aquifers:

Qb	basalt flow
Kd	Dakota Fm.
Jmw	Morrison Fm., Westwater Canyon Mbr.
Jt	Todilto Fm.
Ps	San Andres Ls.
Pym	Yeso Fm, Meseta Blancha Mbr.

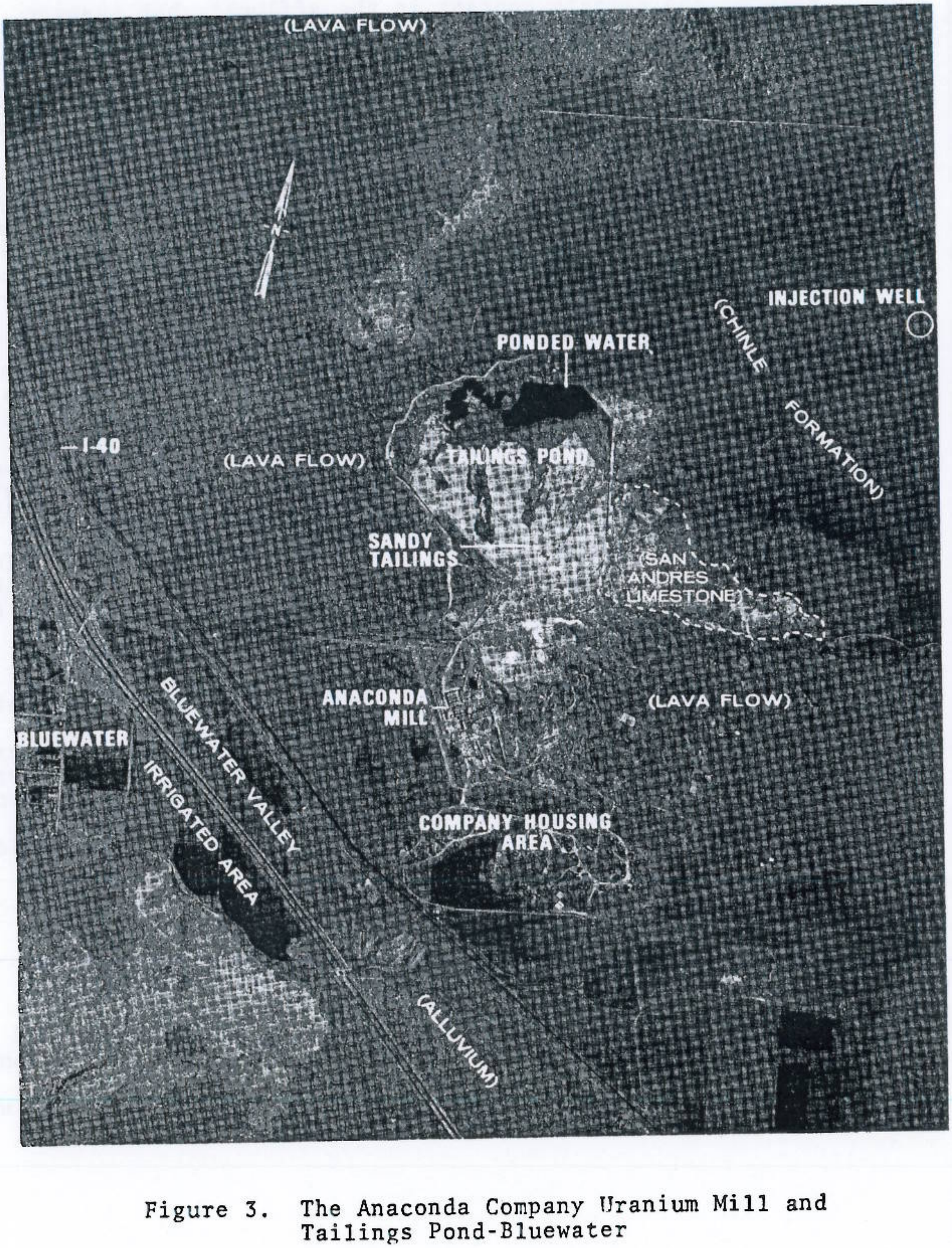


Figure 3. The Anaconda Company Uranium Mill and Tailings Pond-Bluewater

reduced the nitrate content in the effluent, but seepage has continued at a rather high rate, averaging 182.9 x 10^6 liters per year for 1973-1974 (Gray, 1975). The average volume injected in the same period was 348 x 10^6 liters. Therefore, the seepage:injection ratio is 0.53. In essence, one third of the waste stream portion not evaporated enters the shallow aquifer. Assuming that this ratio applies to the period 1953-1960, seepage is estimated at 3200 x 10^6 liters or 845 million gallons. From 1953 to mid-1960, the seepage fraction was probably larger, but is unknown. Discounting this seven-year period and assuming an average radium concentration of 125 pCi/1, seepage has introduced 0.41 curies of radium to the shallow aquifer, which is very definitely potable.

The New Mexico Department of Public Health (1957) compared pre-1955 and 1956-1957 nitrate data for nearby wells completed in alluvium and in the San Andres Limestone. It was concluded that nitrate contamination occurred between 1955 and 1957 after only two years of milling. At the time of the field study (June-Nov., 1956), it was estimated that 87 percent of the effluent leaked from the 28.4 hectare pond at a rate of about 10,000 liters/minute. The plant manager at the time expected that slimes in the waste would seal the bottom of the lagoon in about a year. However, the present loss rate of 347 liters/minute from a ponded area of about 14.4 hectares shows that leakage continues.

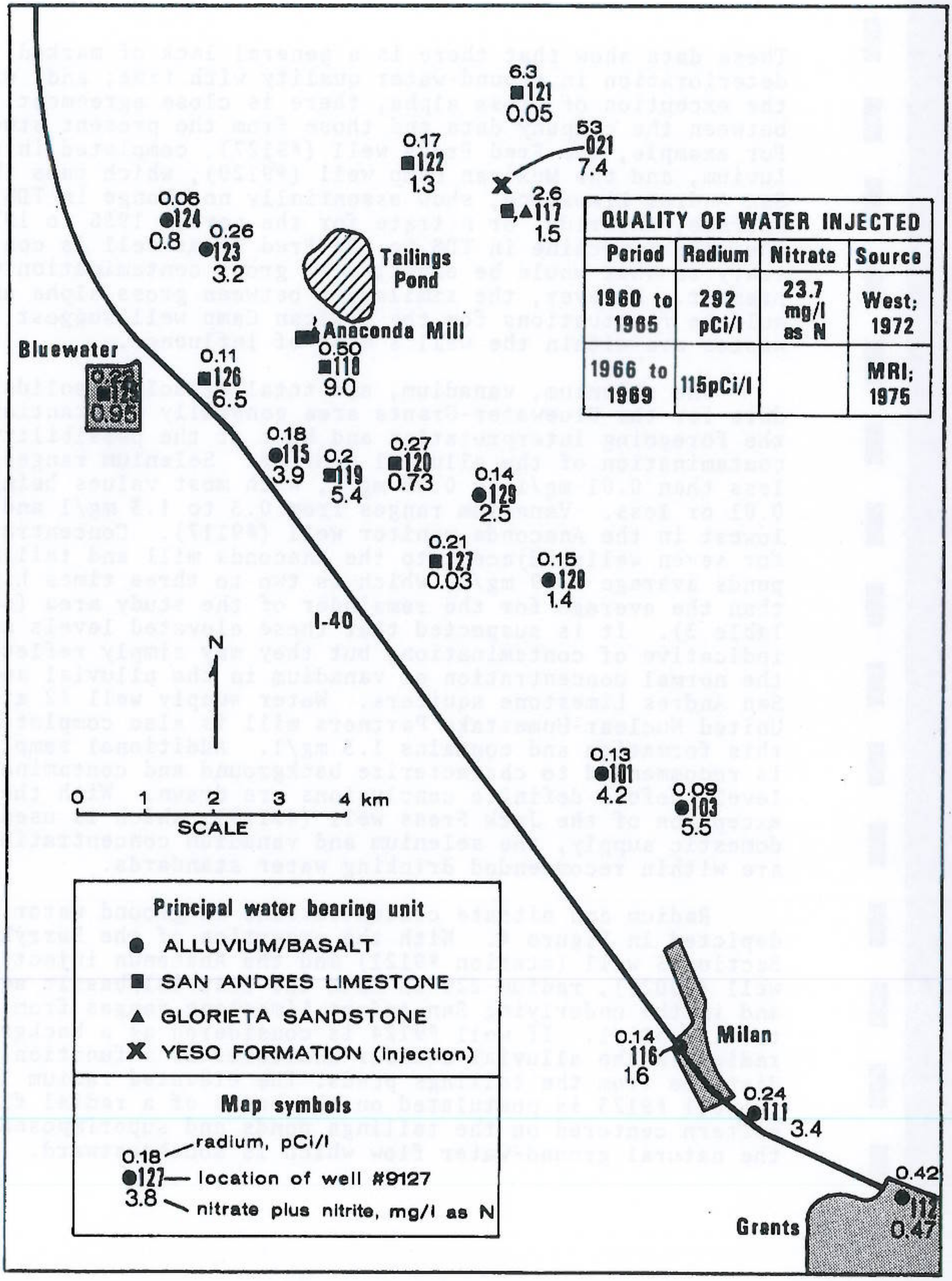
As of May 1957, two wells in the shallow aquifer and three in the deep (San Andres Limestone) aquifer had nitrate concentrations of 66 to 84 mg/1 (15-19 mg/1 NO_3-N), and elevated nitrate levels were present as far as 10 kilometers downgradient from the lagoon or 4.5 kilometers from the Grants supply wells. At the present time, the maximum nitrate concentrations in the bedrock and alluvial aquifers within 4 kilometers of the ponds are 39 and 17.3 mg/1. Concentrations in two wells midway between the ponds and Grants average 21.5 mg/1. In the 1956 study it was also concluded that high nitrate within 4.5 kilometers of Grants was a result of waste disposal. This would imply movement of 10 kilometers in 2 to 3 years, which is extremely unlikely.

To evaluate ground-water quality trends, available nitrate (expressed as nitrate), TDS, chloride, sulfate and gross alpha data (from the foregoing study, from the Anaconda Company (Gray, 1975), and from the present investigation), were plotted to determine changes in ground-water quality with respect to distance from the tailings ponds and with time.

These data show that there is a general lack of marked deterioration in ground-water quality with time; and, with the exception of gross alpha, there is close agreement between the company data and those from the present study. For example, the Fred Freas well (#9127), completed in alluvium, and the Mexican Camp well (#9120), which taps the San Andres Limestone, show essentially no change in TDS, sulfate, chloride, or nitrate for the period 1956 to 1975. The slight decline in TDS in the Fred Freas well is contrary to what would be expected if gross contamination was present. However, the similarity between gross alpha and sulfate fluctuations for the Mexican Camp well suggest that wastes are within the well's area of influence.

The selenium, vanadium, and total dissolved solids (TDS) data for the Bluewater-Grants area generally substantiate the foregoing interpretation and hint at the possibility of contamination of the alluvial aquifer. Selenium ranges from less than 0.01 mg/l to 0.02 mg/l, with most values being 0.01 or less. Vanadium ranges from 0.3 to 1.3 mg/l and is lowest in the Anaconda monitor well (#9117). Concentrations for seven wells adjacent to the Anaconda mill and tailings ponds average 0.89 mg/l, which is two to three times higher than the average for the remainder of the study area (see Table 3). It is suspected that these elevated levels are indicative of contamination, but they may simply reflect the normal concentration of vanadium in the alluvial and San Andres Limestone aquifers. Water supply well #2 at the United Nuclear-Homestake Partners mill is also completed in this formation and contains 1.3 mg/l. Additional sampling is recommended to characterize background and contaminated levels before definite conclusions are drawn. With the exception of the Jack Freas well (#9129), which is used for domestic supply, the selenium and vanadium concentrations are within recommended drinking water standards.

Radium and nitrate concentrations in ground water are depicted in Figure 4. With the exception of the Berryhill Section 5 well (station #9121) and the Anaconda injection well (#9021), radium-226 in both the alluvial/basalt aquifer and in the underlying San Andres Limestone ranges from 0.06 to 0.42 pCi/l. If well #9124 is considered as a background, radium in the alluvial aquifer decreases as a function of distance from the tailings ponds. The elevated radium level in well #9123 is postulated on the basis of a radial flow pattern centered on the tailings ponds and superimposed on the natural ground-water flow which is southeastward. In



QUALITY OF WATER INJECTED

Period	Radium	Nitrate	Source
1960 to 1965	292 pCi/l	23.7 mg/l as N	West; 1972
1966 to 1969	115pCi/l		MRI; 1975

Figure 4. Radium and Nitrate Concentrations in Ground Water in the Grants-Bluewater Area

this direction, wells #9115, #9129, #9128, #9101, and #9103 could also be affected. The gradually reduced concentrations along the flow path may reflect dilution and sorption effects or they may simply be coincidental. For unknown reasons, the trend reverses in the Milan-Grants area, and concentrations begin to increase along the flow path. With the exception of wells #9101 and #9103, essentially the same pattern is true for nitrate. Variations in chloride, which is also a likely indicator of mill effluent, do not fit the pattern for radium and nitrate and, to some extent, weaken the conclusion that contaminants are recognizable in the alluvium.

In the San Andres Limestone and Glorieta Sandstone, radium concentrations range from 0.11 to 2.6 pCi/l (0.11 to 0.50 if well #9117 is excluded) and show no pronounced lateral trends. The highest concentrations (2.6 pCi/l) are in the Anaconda monitor well (#9117) and may indicate contamination (or this may simply be a naturally elevated level in the Glorieta Sandstone). Very few wells tap this formation and water quality is poorly known. Anaconda well #2 (#9118) is also relatively high in radium, nitrate, and polonium-210. It is quite possible that the well is contaminated by downward seepage of wastes from the tailings pond.

The Berryhill Section 5 well (#9121) is listed in the Anaconda Company records as being completed in the alluvium. It is equipped with a windmill and is used for stock watering. However, Gordon (1961) indicates that as of January 1958 there were two wells in the area. The active well, 221 meters deep and completed in the San Andres Limestone, replaced an older well, 107 meters deep and completed in the Chinle Formation. Therefore, contamination of either the Chinle Formation or the San Andres Limestone by injected wastes is occurring insofar as the radium-226 concentration of 6.3 pCi/l in the Berryhill Section 5 well greatly exceeds normal concentrations in either formation (see also Table 4).

Because of excessive seepage from the tailings ponds, the Anaconda Company developed an injection well to dispose of decanted effluent. According to company and U. S. Geological Survey reports (Fitch, 1959; West, 1972), favorable geologic, hydraulic and water quality conditions exist to allow this disposal method. However, subsequent evaluation of the monitoring data and inadequacies in the number and location of monitoring wells make this conclusion questionable.

From 1960 to date, injection has been into the Yeso and Abo Formations at depths of 289.6 to 433.7 meters. Between the injection zone and the lowermost potable aquifer, there is reportedly a relatively impervious sequence of sedimentary rocks, including numerous anhydrite and gypsum beds (Fitch, 1959; West, 1972). When the injection program was conceived in 1960, this sequence was considered sufficient protection for the overlying potable aquifers. Also, it was reasoned that when the waste fluid contacted the gypsum or anhydrite, as well as other disposal zone rocks, an ion exchange occurred between radium (in the fluid) and calcium (in the reservoir rocks), thereby reducing somewhat the radium concentration in the injection fluid.

Based on laboratory tests of the drill cores from the disposal zones, neutralization of the waste effluent was expected to occur. The pH of the formation waters ranges from 7.4 to 8, while the effluent has a pH of about 2.2. It was thought that the acid effluent becomes neutral or slightly basic due to the preponderance of disposal zone waters. Radium solubility would, therefore, decline. The disposal zone waters have been shown to be non-potable due to their brackish quality. Chemical analyses indicate a very high concentration of total dissolved solids, and it was reasoned that contamination of the deeper formations would not deny foreseeable use for the contained water.

Evidence of leakage from the injection zone is shown in Figure 5, which summarizes Anaconda Company data on the volumes of wastes injected from 1960 through 1973. Also shown are trends in natural uranium and chloride from the monitor well #9117, Roundy windmill, and North well (#9122) for the period 1969 through 1973. It is readily apparent that both chloride and uranium concentrations in all three monitoring wells are increasing with time and vary directly with the volumes of waste injected. The concentration of polonium-210 in the Monitor well exceeds that in all other wells in the Bluewater-Grants area and is well above the average of 0.33 pCi/l for six wells in bedrock. Concentrations of chloride and natural uranium in the waste water average 2010 ppm and 7340 pCi/l, respectively, for the period 1960 to 1965 (West, 1972). Radium from 1960 through 1969 averages 221 pCi/l (Clark, 1974). According to the partial chemical data for these three monitoring wells and contrary to original projections, contamination apparently extends into the San Andres Limestone.

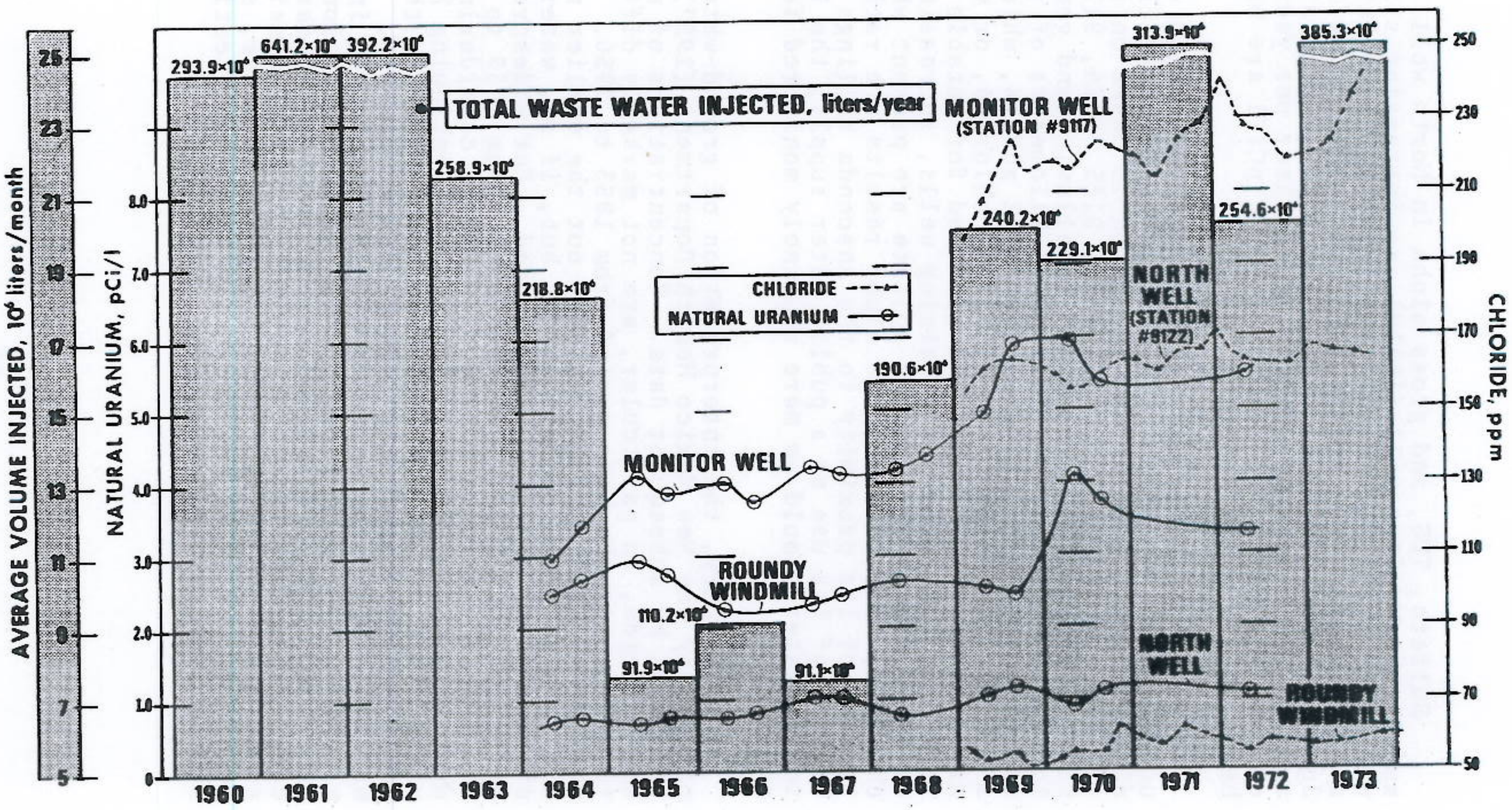


Figure 5. Summary of Waste Volumes Injected via the Anaconda Disposal Well and Water Quality in Selected Monitoring Wells

Sulfate, TDS, and gross alpha in North well (#9122) and in the Monitor well (#9117) are increasing slightly with time. For North well, TDS increased at a rate of about 13 mg/l per year and has gone from 1680 mg/l in June 1956 to 1900 mg/l in February 1975. Gross alpha is apparently increasing about 0.1 pCi/liter per year, but the company analytical results of about 2 pCi/l are markedly below the 30 pCi/l reported herein.

At the present time, ground water developed for potable use does not appear to be adversely affected by the Anaconda disposal practices. This conclusion is based on analyses for seven wells (9118, 9119, 9124, 9125, 9126, 9127 and 9129) completed in bedrock and in alluvium and generally located peripheral to and within 4 kilometers of the tailings ponds. Anaconda supply wells #2 and #4, which show slightly increasing trends for TDS, chloride, or sulfate, are closest to the ponds and are used for potable and mill feed purposes. For the remaining wells, increasing and decreasing trends for TDS and sulfate are present whereas chloride, nitrate and gross alpha results are rather stable. Because of its proximity to the Anaconda tailings ponds and because of its use as a public water supply, the LDS well in Bluewater should be more routinely monitored for nitrate and radium.

In summary, the interpretation of ground-water quality offered by the New Mexico Health Department (1957) is not supported by subsequent data. Concentrations of nitrates and chloride, in particular, are not markedly different today than in the base period from 1953 to 1956. Data for the period 1956 to 1969 may bear out the earlier predictions of gross contamination; but, if so, water quality since 1969 is only slightly changed. For widespread ground-water contamination to quickly occur from 1955 to 1956 and then rapidly attenuate is very unlikely considering the dynamics of ground-water flow and the continuing history of waste disposal. It is a matter of conjecture whether the earlier data were faulty or were misinterpreted. Ground-water flow patterns in the vesicular basalt and interbedded alluvium underlying the northwest pond and portions of the main pond are not described in the available references. Complex permeability distributions and waste density considerations add further complications. However, seepage is occurring and it is possible that the Company estimates stated above are conservative.

The foregoing comments do not imply that ground-water contamination is absent. Gross contamination of nearby wells, or a continuation of the earlier, perhaps erroneous predictions of contamination, is not apparent. The major qualification of these conclusions is that wells properly located and completed for sampling purposes are not available; hence, the extent of contamination is not well understood. Contamination is evident in the North and Monitor wells but is not yet a problem. Available chemical data for pre- and post-injection periods should be evaluated, together with monthly or quarterly injection volumes, to further confirm or deny the trends shown in Figure 5. If the trends shown are valid, thorough reevaluation of the injection method of waste disposal and construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Such measures are particularly important if increasing concentrations of radium-226 (and possibly lead-210) are appearing in the aquifers above the injection zone.

United Nuclear-Homestake Partners Mill and Surrounding Area

The mill is partially surrounded on the southwest or downgradient side by housing developments and irrigated farm lands, both of which depend on local ground-water supplies. Also obvious in Figure 6 is a darker seepage area around the base of the tailings pile. The seepage is collected and pumped back to the pond above the sandy tailings, but seepage from the pile proper and from the encircling moat can enter the ground-water reservoir. The five-sided polygon adjacent to the mill buildings is an inactive tailings pile that was formerly part of the Homestake-New Mexico Partners mill. In the upper left-hand portion of the photograph is shown the terminus of the San Mateo Creek drainage from the San Mateo and Ambrosia Lake areas.

Three distinct aquifers are present in the area of the mill and surrounding developments. In ascending order, these include the San Andres Limestone, the Chinle Formation, and the alluvium. Water table conditions and a southwestward lateral flow gradient prevail in the latter, with static water levels about 15 meters below land surface. The San Andres Limestone originally was under artesian head, but heavy pumping for irrigation and for industry has removed much of the head once present. Data presented by Gordon (1961) indicate a downwind flow gradient, but the permeability of the Chinle Formation is low, and actual vertical

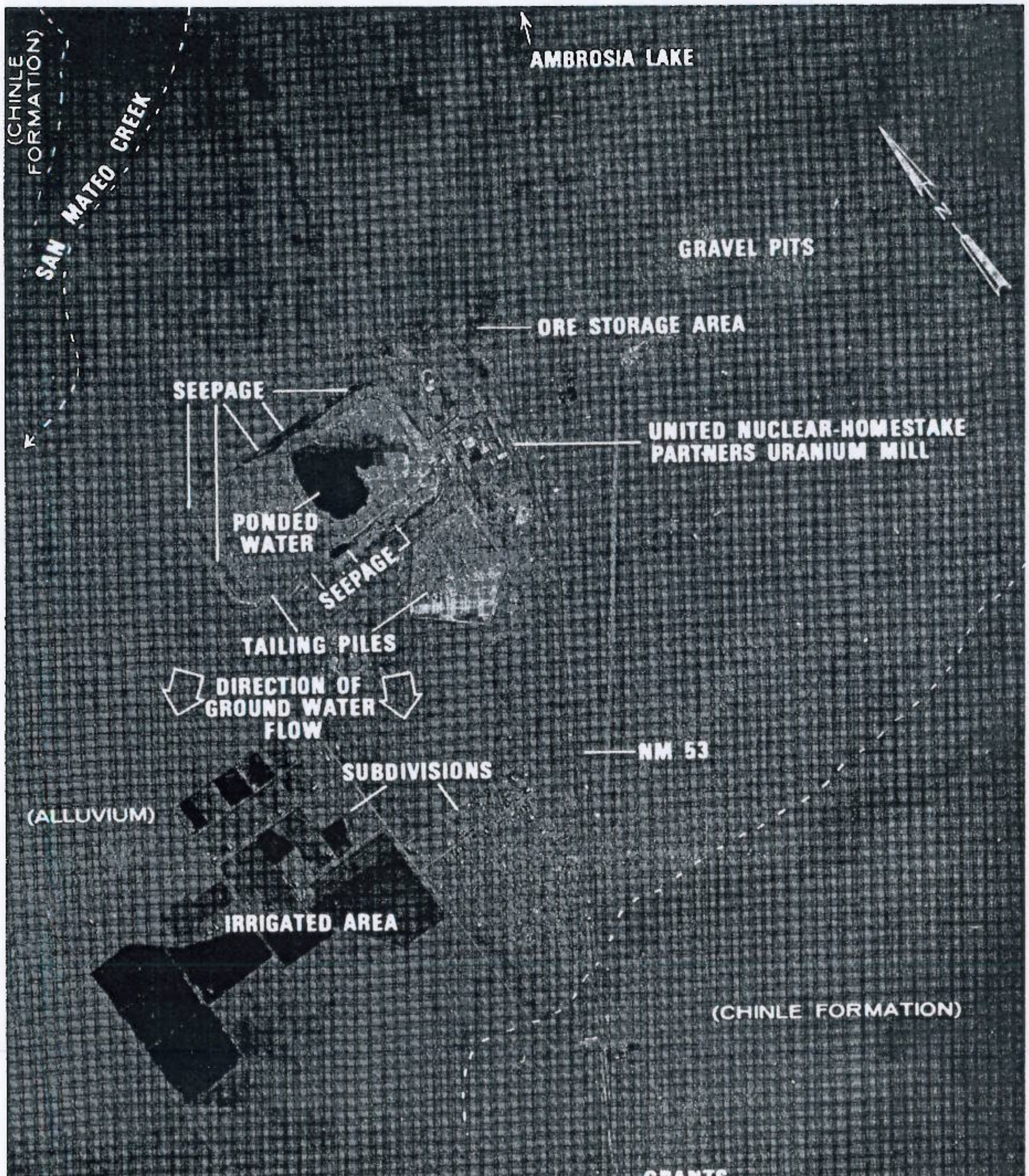


Figure 6. The United Nuclear-Homestake Partners Uranium Mill and Tailings Ponds-Milan

water transfer is probably minimal. The chief significance of these hydrogeologic conditions is that liquid effluents produced by the uranium milling operation are likely to infiltrate at the mill site and travel in a south-southeast direction toward the nearby subdivisions. Water quality in the Chinle Formation and the still deeper San Andres Limestone is likely to be unaffected.

Radium concentrations in groundwater (Figure 7) from the San Andres and Chinle range from 0.05 to 0.27 pCi/l, with a mean of 0.16 pCi/l for six determinations. Realistically, assuming that minimum detectable amount is 0.1 pCi/l versus 0.05, the average increases to 0.18 pCi/l. The peak value from shallow wells tapping the water table aquifer in the alluvium is 1.92 pCi/l in well D, the single active monitoring well (#9135). Although below the PHS drinking water standard of 3 pCi/l, this value does indicate movement of contaminants away from the tailings pond. Attenuation due to sorption may mask a very sharp concentration gradient between this well and the pond. At a distance of approximately 0.6 kilometers from the ponds, radium in the shallow aquifer reverts to levels of 0.13 to 0.72 pCi/l and averages 0.36 pCi/l, or about twice that present in the bedrock reservoirs at depth. Relatively high concentrations (0.72, 0.61 pCi/l) in the Worthen and Enyart wells may reflect plumes or fronts of contaminants that have advanced ahead of the main body. The water table map (Figure 8), prepared by Chavez (1961), portrays an elongated, northeast-trending lobe or mound centered on the smaller tailings pile from the now inactive Homestake-New Mexico Partners mill.

The possibility of ground-water pollution from the United Nuclear-Homestake Partners tailings pond was noted in the early 1960's (Chavez, 1961). Samples from on-site monitoring wells completed in the alluvium contained from 0.8 to 9.5 pCi/l radium despite the fact that ore had been processed for less than two years. These concentrations are markedly above the normal range of 0.1 to 0.4 pCi/l in wells several miles west of the mill and from wells in the alluvium between San Rafael and Grants.

Chloride and TDS data for well #9107 (Figure 7) support the idea of a tongue of contaminated ground water in the area between this well and the tailings pile. Nitrate in this well was 62 mg/l and, therefore, does not meet the PHS Drinking Water Standard of 45 mg/l. Infants and fetuses are particularly susceptible to nitrate poisoning at concentrations above 45 mg/l, and alternate sources of potable water should be utilized. Heterogeneities in sediment permeabilities, coupled with irregular induced flow gradients resulting

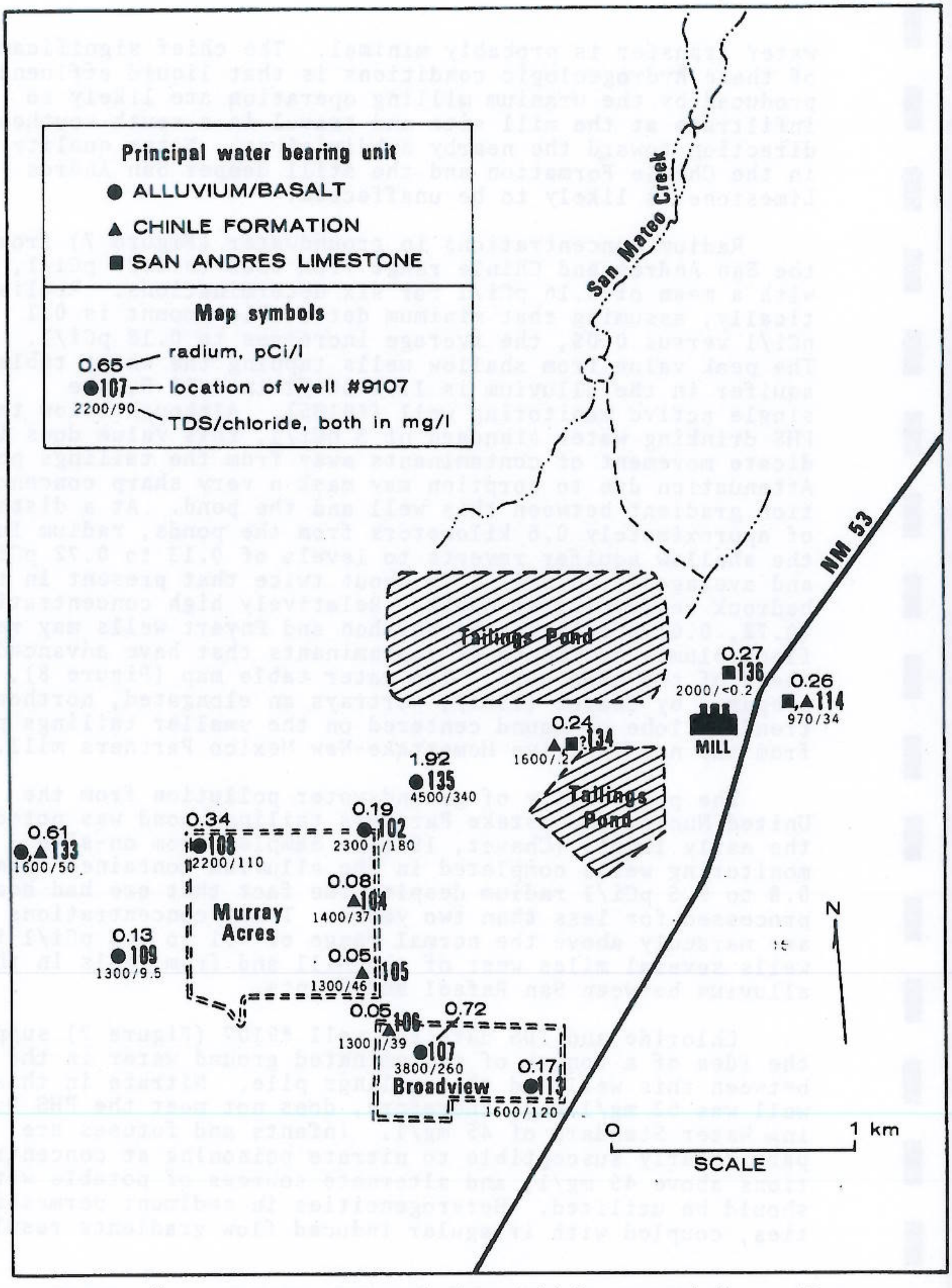


Figure 7. Radium, TDS and Chloride in Ground Water Near the United Nuclear-Homestake Partners Mill

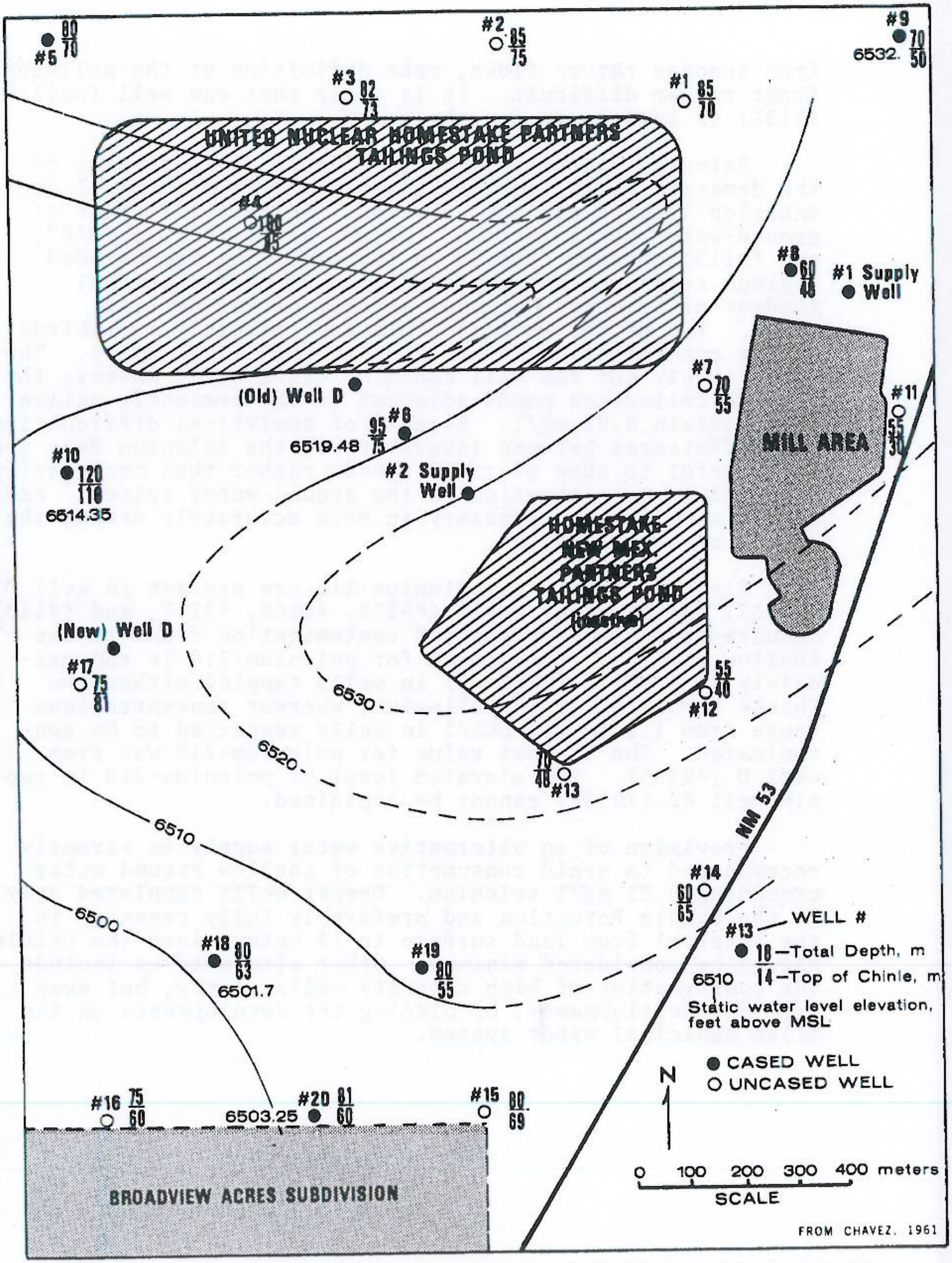


Figure 8. Water Table Contours and Well Locations at the United Nuclear-Homestake Partners Mill Site

from seepage return flows, make definition of the polluted front rather difficult. It is clear that one well (well D, #9135) is inadequate for the task.

Selenium concentrations (see Table 3) in several of the domestic wells located downgradient from the mill are anomalously high and are, perhaps, the best indicator of ground-water contimination. Nearby wells (#9102, #9107, and #9113) contain from 20 to 106 times the recommended maximum selenium concentration of 0.01 mg/l (National Academy of Sciences-National Academy of Engineering, 1972). Two of the wells contain approximately two-thirds of the concentration in the monitor well (1.52 mg/l). The water supply for the mill contains <0.01 mg/l, whereas the seepage collection ponds adjacent to the presently active pile contain 0.92 mg/l. Because of analytical difficulties and differences between laboratories, the selenium data are most useful to show elevated trends rather than necessarily an absolute concentration in the ground-water system. Additional sampling is necessary to more accurately define the extent of contamination.

Elevated levels of polonium-210 are present in well D (#9135) and in other wells (#9102, #9106, #9107, and #9113) downgradient from a suspected contamination front in the shallow aquifer. Background for polonium-210 is approximately 0.34 pCi/l (Table 5) in wells tapping either the Chinle Formation or the alluvium, whereas concentrations range from 1.0 to 2.3 pCi/l in wells suspected to be contaminated. The highest value for polonium-210 was from well D (#9135). The elevated level of polonium-210 in supply well #2 (#9134) cannot be explained.

Provision of an alternative water supply is strongly recommended to avoid consumption of shallow ground water exceeding 0.01 mg/l selenium. Deeper wells completed only in the Chinle Formation and preferably fully cemented in the interval from land surface to 15 meters into the Chinle should be considered minimum. Other alternatives include the construction of high capacity wells nearby, but away from the developments, or placing the developments on the Milan municipal water system.

Ambrosia Lake Area

The Kerr-McGee mill is located on the dip slope of a southeast-facing cuesta in an area underlain by a thin veneer of silt and clay alluvium over the Mancos Shale. Shown in Figure 9 is the large network of tailings ponds and water storage reservoirs built by excavation and by selectively sorting the coarse tailings for retention dams. Discharge from numerous mines and from ion exchange plants gives rise to perennial flow in Arroyo del Puerto which trends north-south. Seepage from the tailings ponds and from the aforementioned sources is evident from the vegetation present in the formerly dry washes. Shown in the upper right corner of the photograph, taken in September 1973, is the inactive tailings pile at the United Nuclear Corporation mill. The ponded water shown on the pile has since evaporated or seeped into the tailings.

Ground-water sampling in the Ambrosia Lake area focused on the Kerr-McGee tailings disposal operation and the combined impact of various ion exchange plant and mine water discharges into San Mateo Creek and Arroyo del Puerto. Because of influent stream conditions, these surface water bodies represent line sources of recharge to the shallow ground-water reservoir. Of the 22 wells sampled in the area (see Figure 10), all but 3 were part of the Kerr-McGee Nuclear Corporation environmental monitoring network. The absence of sampling points near the United Nuclear mill and tailings pile or near the active mines and ion exchange plants precluded study in these areas. Poorly understood are the effects of seepage from settling ponds and from open channels leading to the two principal streams in the area. The disposition of solutions involved <u>in situ</u> leaching is also unknown.

Nevertheless, the conservative parameters clearly indicate the infiltration of wastewater. Whereas shallow ground water beneath San Mateo Creek contains about 700 mg/l TDS in the reach above Arroyo del Puerto, the reach below has about 2000 mg/l. Ammonia increases four fold from 0.05 to 0.22 mg/l, and nitrite plus nitrate (as N) go from an average of less than 1 mg/l to 24 mg/l. The recommended maximum in drinking water is 10 mg/l. Selenium and vanadium concentrations in ground water do not markedly increase near the tailings ponds. One exception is well KM-43 (#9208) which contains 0.29 mg/l selenium as well as high radium and TDS. The Marquez windmill (#9132) is also enriched in selenium which further substantiates the TDS, chloride, ammonia, and nitrate data results which show contamination of the shallow aquifer. Nitrate, derived from

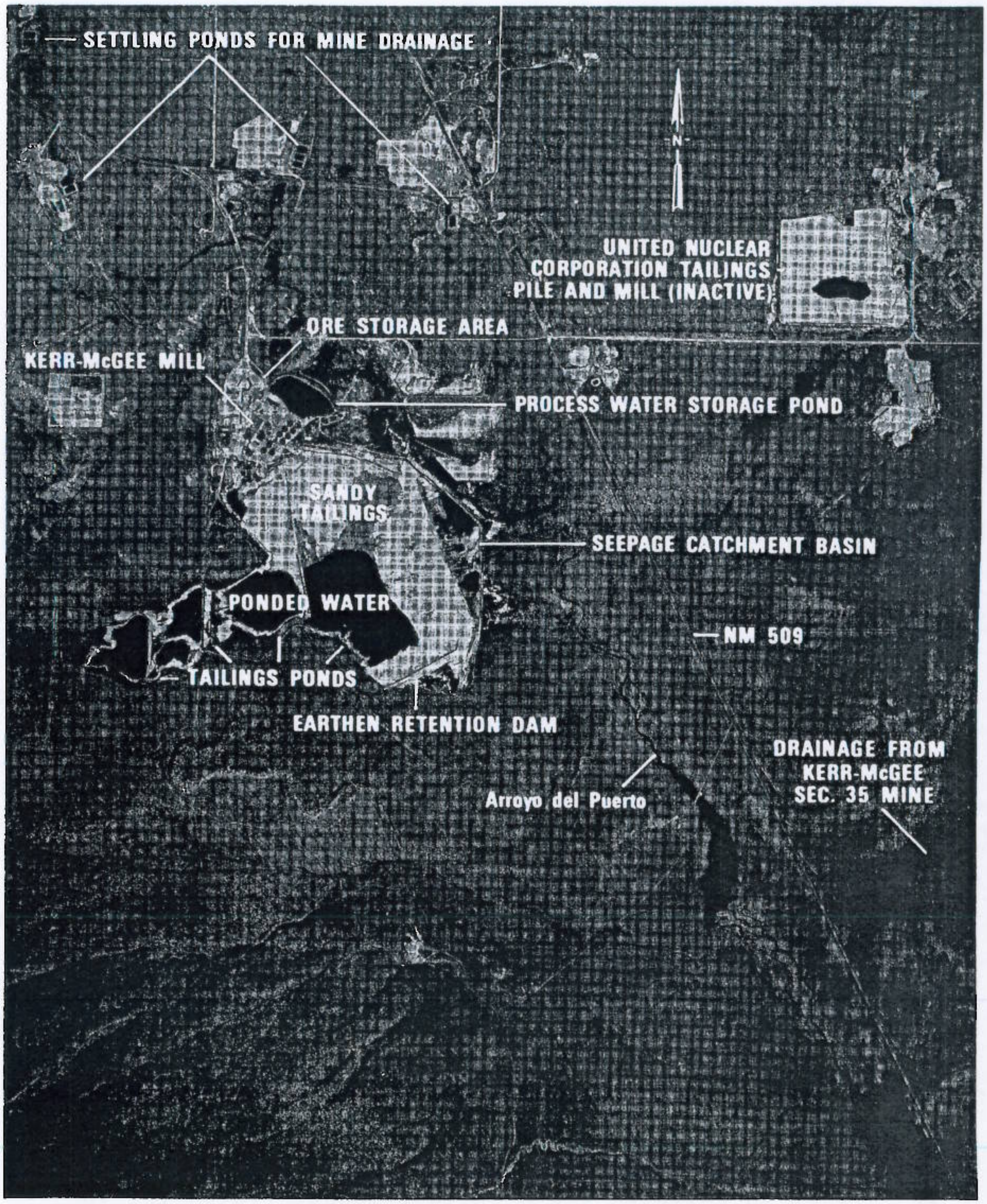


Figure 9. Kerr-McGee Nuclear Corporation Uranium Mill, Tailings Ponds, and Mines-Ambrosia Lake

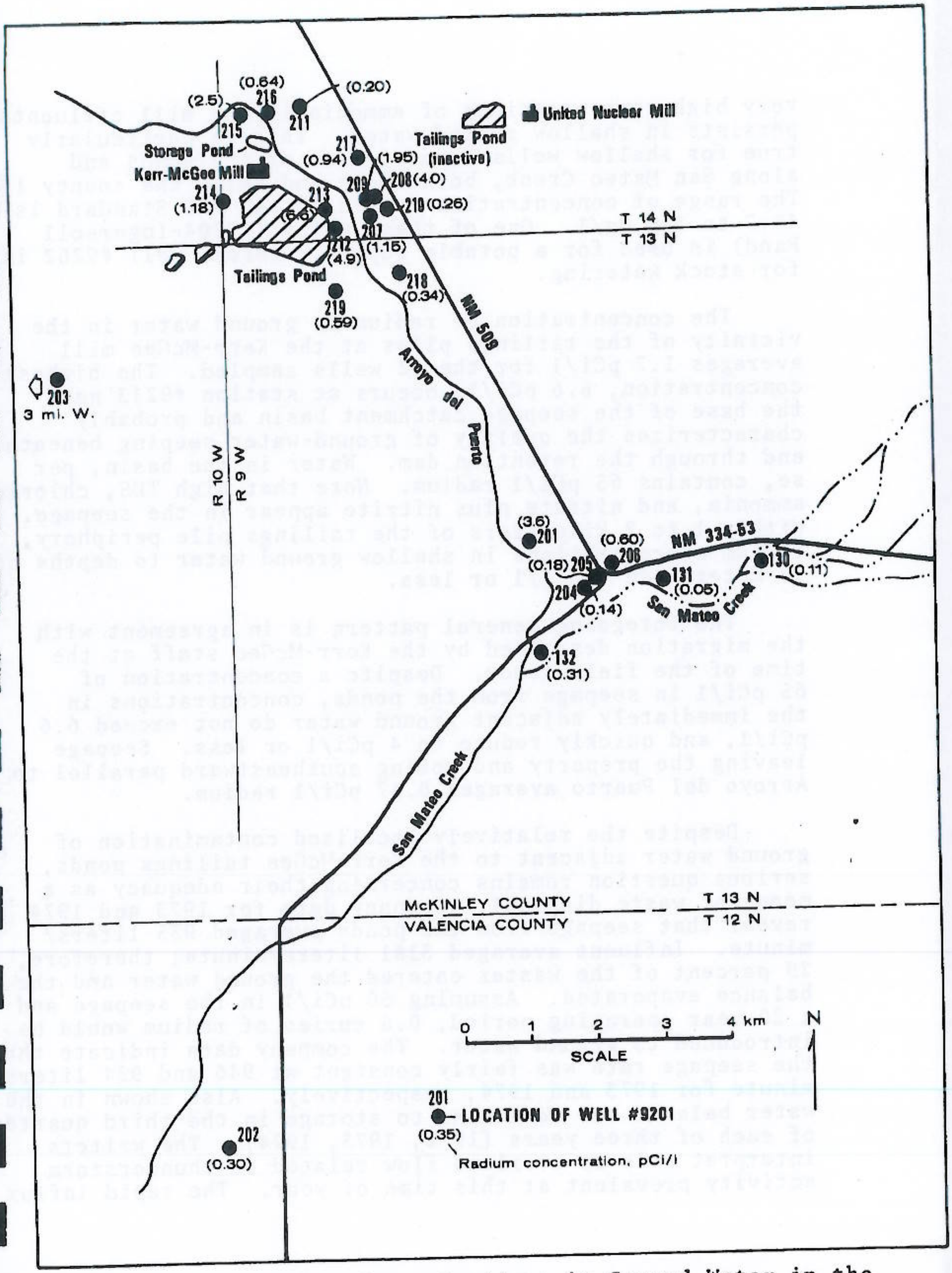


Figure 10. Radium Concentrations in Ground Water in the Ambrosia Lake Area

very high concentrations of ammonia in the mill effluents, persists in shallow ground water. This is particularly true for shallow wells located east of the ponds and along San Mateo Creek, both above and below the county line. The range of concentration exceeding the PHS Standard is 48.7 to 350 mg/l. One of these wells (#9204-Ingersoll Rand) is used for a potable supply, whereas well #9202 is for stock watering.

The concentration of radium in ground water in the vicinity of the tailings piles at the Kerr-McGee mill averages 1.7 pCi/l for the 12 wells sampled. The highest concentration, 6.6 pCi/l, occurs at station #9213 near the base of the seepage catchment basin and probably characterizes the quality of ground-water seeping beneath and through the retention dam. Water in the basin, per se, contains 65 pCi/l radium. Note that high TDS, chloride, ammonia, and nitrate plus nitrite appear in the seepage. Within 1 to 2 kilometers of the tailings pile periphery, radium concentrations in shallow ground water to depths of 17 meters are 4 pCi/l or less.

The foregoing general pattern is in agreement with the migration described by the Kerr-McGee staff at the time of the field study. Despite a concentration of 65 pCi/l in seepage from the ponds, concentrations in the immediately adjacent ground water do not exceed 6.6 pCi/l, and quickly reduce to 4 pCi/l or less. Seepage leaving the property and moving southeastward parallel to Arroyo del Puerto averages 0.47 pCi/l radium.

Despite the relatively localized contamination of ground water adjacent to the Kerr-McGee tailings ponds, serious question remains concerning their adequacy as a means of waste disposal. Company data for 1973 and 1974 reveal that seepage from the ponds averaged 935 liters/minute. Influent averaged 3181 liters/minute; therefore, 29 percent of the wastes entered the ground water and the balance evaporated. Assuming 60 pCi/l in the seepage and a 20-year operating period, 0.6 curies of radium would be introduced to ground water. The company data indicate that the seepage rate was fairly constant at 946 and 924 liters/minute for 1973 and 1974, respectively. Also shown in the water balance are additions to storage in the third quarter of each of three years (1972, 1973, 1974). The writers interpret this as overland flow related to thunderstorm activity prevalent at this time of year. The rapid influx of overland flow into the ponds prompts questions concerning their stability and overall company management practices. The ponds are operated with very little freeboard and the berms or dikes are composed of sandy tailings that are readily eroded, particularly if overflow conditions develop. Catastrophic failure of the tailings ponds could occur.

Churchrock Area

The Puerco River at Gallup was ephemeral until upstream mining operations reached a scale such that wastewater discharge was sufficient to cause perennial flow. At present the combined discharge from the United Nuclear and Kerr-McGee mines, located as shown in Figure 11, is about 16 x 10^6 liters/day and characterized by 8 to 23 pCi/l radium, 700 to 4900 pCi/l uranium, 0.01 to 0.04 mg/l selenium, and 0.4 to 0.8 mg/l vanadium. In terms of radium, selenium, and vanadium, the water is unfit for stock or potable uses and not recommended for irrigation. Infiltration of the mine wastewater represents a remote threat to potable ground water in the vicinity of the Puerco River and possibly part of the Gallup municipal supply. In part, the present study examines whether noticeable ground-water quality deterioration has occurred to date.

Ground-water sampling in the Churchrock area involved 13 wells located along the Puerco River and South Fork Puerco River. For control purposes, an adjacent watershed tributary to the Rio Puerco was also sampled. A single sample from a newly developed well serving the Gallup area was also tested. The sampling points included water used for stock, domestic use, and for public drinking water supplies. Alluvial and bedrock aquifers were sampled in an area of 200 km^2 located generally east and northeast of Gallup.

None of the ground-water samples contain sufficient quantities of naturally occurring radionuclides to constitute a health problem. The radiochemical, trace element, and gross chemical data do not indicate that contamination of ground water is occurring as a result of the mining operations underway. However, two of the wells (#9139, #9221) contain 119.6 and 62 mg/l nitrate, respectively, and, therefore, do not meet the PHS Drinking Water Standard of 45 mg/l. The mine drainage waters contain less than 4 mg/l, hence this is not the source. Consumption of water this high in nitrates is particularly dangerous to infants and the unborn and alternate supplies should be utilized. More suitably located

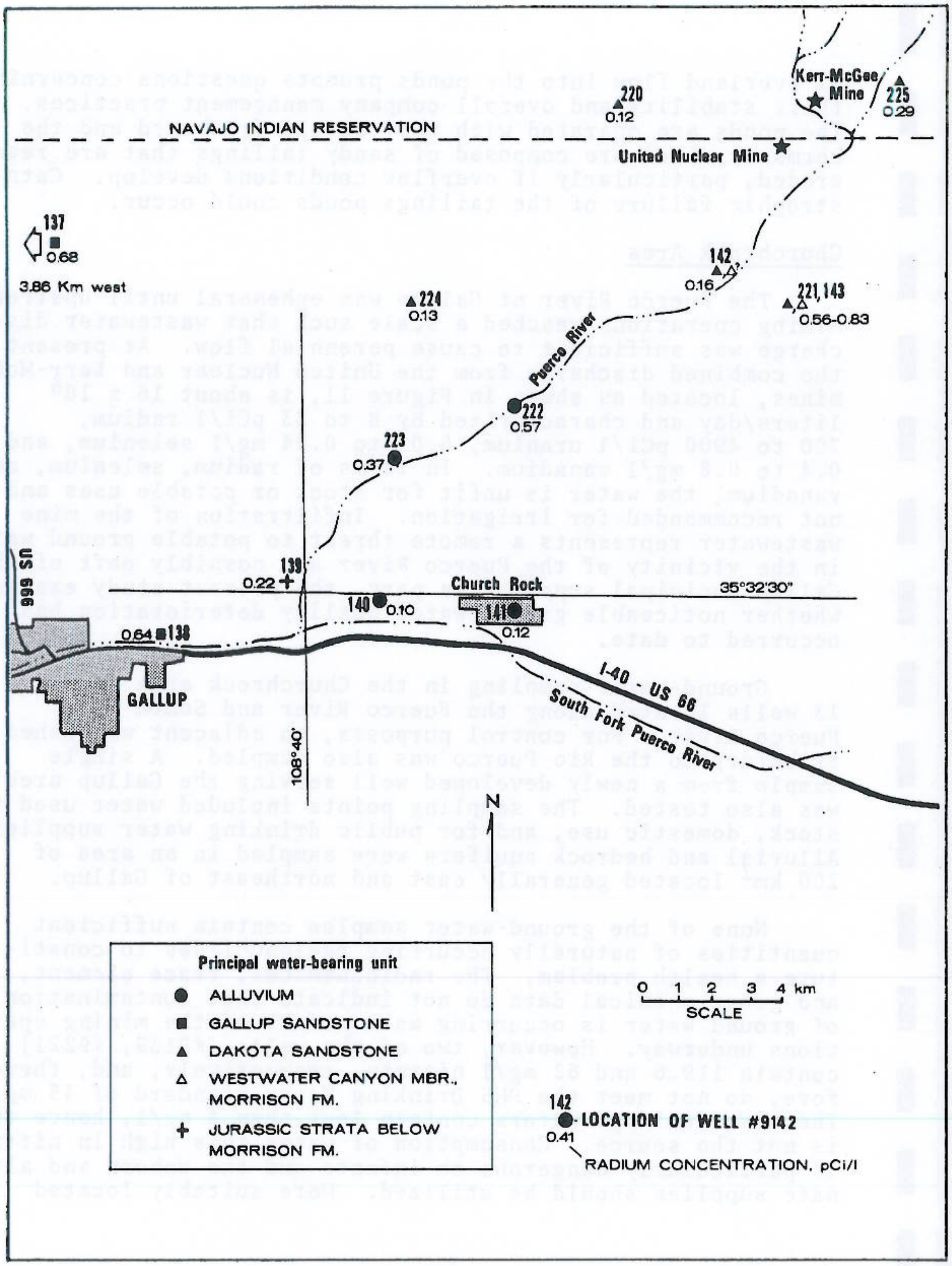


Figure 11. Radium Concentrations in Ground Water in the Churchrock-Gallup Area

sampling points, together with revised analytical programs are strongly recommended improvements to the existing industrial efforts.

By comparison, the effects of mining on the concentration or radium in ground water are pronounced. Present discharge from the Kerr-McGee mine, which is in the development versus mining stage, averages 7.9 pCi/l as compared to 23.3 pCi/l for the United Nuclear mine. The latter is producing ore. In both cases, elevated radium concentrations are present. In large part, these are attributable to mining operations and practices and do not represent natural water quality, evident from samples of ground water collected from 4 wells and 3 long holes, all in the Westwater Canyon Member (Hiss and Kelley, 1975). Radium varied from 0.05 to 0.62 pCi/l compared to 0.28 to 184.8 pCi/l uranium. An additional sample collected in November 1973 from the settling pond discharge at the United Nuclear mine contained 8.1 pCi/l radium and 847 pCi/l natural uranium. Thus, initial penetration of the ore body increased radium at least 10-fold and subsequent mine development work over a two-year period resulted in another three-fold increase. Compared to natural concentrations, radium increased some 23 times. Similar trends also seen in the Ambrosia Lake area prevail, indicating that ultimate radium concentrations on the order of 50 to 150 pCi/l are likely. This has been tentatively confirmed by company, self-monitoring data.

Jackpile-Paguate Area

Sampling in the vicinity of the Jackpile-Paguate open pit uranium mine included four wells located as shown in Figure 12. One of these (#9233) is the Paguate municipal supply which is a flowing artesian well completed in alluvium at a depth of 22.9 meters. The remaining three wells are property of the Anaconda Company and are used for potable supply and for equipment washing, etc. It is believed that all three were former exploration holes that have been reamed out, cased, and equipped with a submersible pump. The water quality is probably representative of the Jackpile Sandstone Member of the Morrison Formation, which also is the principal ore body in the Laguna mining district.

Dissolved radium in water from the Jackpile Sandstone aquifer ranges from 0.31 to 3.7 pCi/l. The latter value is from the new shop well which is a source of potable and nonpotable water for the facility. Continued consumptive use of this water is not recommended because the radium exceeds the PHS Drinking Water Standard of 3 pCi/l.

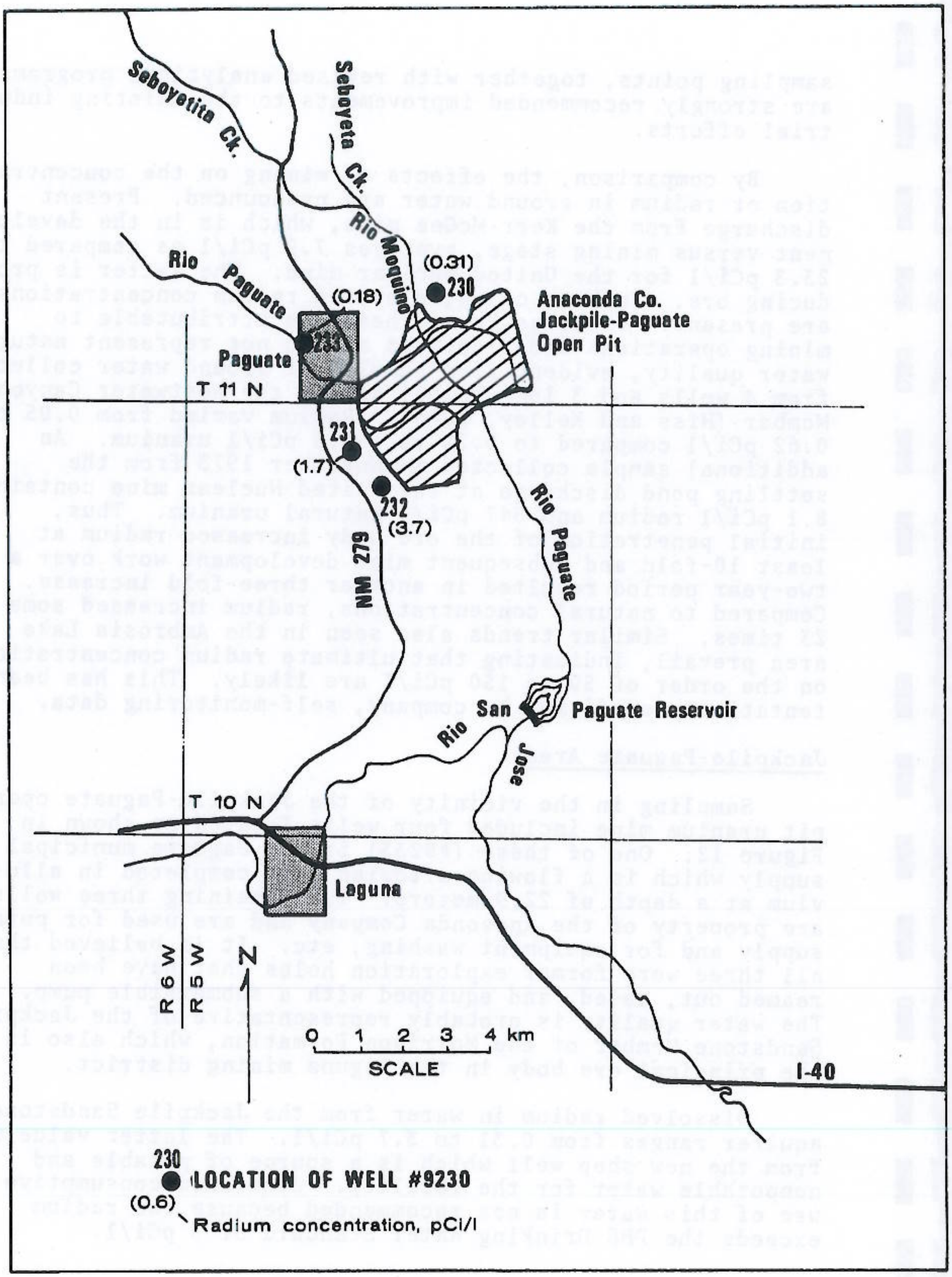


Figure 12. Radium Concentrations in Ground Water in the Paguate-Jackpile Area

The village of Paguate water supply is well below the recommended maximum level for not only radium but also the other isotopes considered in the present study. Selenium, however, is at the maximum recommended level of 0.01 mg/1. It is extremely unlikely that the present shallow-well supply will be affected by mining unless the open pit would be extended close to the well field. Recharge to the shallow aquifer is derived from runoff which infiltrates to the west and north. After percolating southward, it then reappears in a marshy area west of the village. Springs and artesian conditions are likely the result of decreasing transmissivity due to the near surface occurrence of shales and poorly permeable sandstones in the lower reaches of Pueblo Arroyo.

The downstream impacts of the Jackpile-Paguate mine on ground water were not determined because of the absence of suitable sampling points. It is recommended that shallow monitor wells be installed at several points along the Rio Paguate to ascertain the chemical, radiochemical, and trace element species present. Limited coring in the sediment-filled Paguate reservoir would provide data on variations in the radium and uranium content before and during mining. Such data would also provide information on radioactivity associated with sediment transport during periods of peak runoff and erosion.

Significance of Radiological Data

Regulations and Guidelines

On August 14, 1975, the U.S. EPA published in the Federal Register (40 FR158, p. 34323-34328) a "Notice of Proposed Maximum Contaminant Levels for Radioactivity" to be included in 10 CFR Part 141 - Interim Primary Drinking Water Regulations. The following are the proposed maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

1. Combined radium-226 and radium-228 not to exceed 5 pCi/1.

2. Gross alpha particle activity (including radium-226 but exclusive of radon and uranium contents) not to exceed 15 pCi/1.

The proposed regulations also discuss maximum contaminant levels of beta particle and photon radioactivity from man-made radionuclides.

Therefore, with respect to these proposed radioactive contaminant levels, the following conclusions were reached:

1. Additional analysis for radium-228 and lead-210 will proceed and be reported in a separate report at a later date.

2. Since radium-228 is a daughter product of thorium-232 and thorium analyses of these waters fluctuated around background concentrations, it appears that the radium-228 content should also be at background levels (i.e., less than 0.02 pCi/l. Hence, the radium-228 content, under assumed equilibrium conditions, should be less than 0.042 pCi/l, the highest reported thorium-232 content.

3. Only two locations out of the 71 ground-water locations sampled have radium-226 concentrations in excess of 5 pCi/l. Therefore, the proposed new standard of 5 pCi/l for combined radium-226 and radium-228 contents is therefore exceeded at these two locations.

4. Sixty of the 71 ground-water locations had gross alpha results in excess of the proposed 15 pCi/l limit; however, the gross alpha results reported here include uranium isotopes. Included in the list of sixty locations are several locations where the gross alpha results are less than 15 pCi/l, but consideration of the 2 sigma confidence level would then indicate a gross alpha possibly in excess of the 15 pCi/l limit.

5. The proposed maximum gross beta limit excludes naturally occurring radionuclides (e.g., lead-210); therefore, there is no presently proposed maximum contaminant level for lead-210. The NMEIA population guide MPC of 33 pCi/l appears to be the only current applicable guideline for lead-210 content.

Since the above radioactivity contaminant levels are proposed and not final interim primary drinking water regulations, the following discussions of the radiological analyses of water samples obtained during this study will be based on the U.S.P.H.S. Drinking Water Standards (1962) and current NRC/NMEIA maximum permissible concentration levels.

Radium-226

Of the 71 ground-water sampling locations of this study, only 6 locations showed radium-226 concentrations in excess of the 3.0 pCi/l drinking water standard (U.S.P.H.S. Drinking Water Standards, PHS Publication

No. 956; 1962). The population guide--maximum permissible concentration (10CFR, Part 20, Table II, column 2, unrestricted areas) is 10 pCi/l for radium-226. Table 7 lists the 6 locations and presents the gross alpha and radium-226 results.

The Jackpile-New Shop well, Paguate (#9232), is a potable water supply having a radium concentration in excess of the drinking water standard. This water need not be used for human consumption since other nearby wells have much lower radium concentrations (e.g., the Paguate municipal supply (#9233) or the Jackpile well (#9230)).

The Phil Harris well, Grants (#9201), is the only other potable water supply with a radium concentration in excess of 3.0 pCi/l. The Berryhill Section 5 windmill, Bluewater (#9121), is used as a stock water supply; and since there are no nearby human consumers, the radium concentration of 6.3   0.1 pCi/l is of no immediate health hazard.

Samples from two Kerr-McGee monitoring wells (#9208 and #9213), located within 800 meters of the main tailings retention dam, contain radium in excess of 3.0 pCi/l. These wells are not fitted with pumps, are in a restricted area, and contain water otherwise unfit for comsumption. For example, TDS varies from 7500 to 8900 mg/l. Therefore, these wells do not constitute a health hazard in terms of dissolved radium. Similarly, station #9212 consists of seepage return water collected at the base of the retention dam. Aside from the radium content of 4.9 pCi/l, the water is in a restricted area, is not used for any purpose, and contains 36,000 mg/l TDS. Therefore, consumptive use and creation of a health hazard is extremely unlikely.

For comparison purposes, Table 8 shows the radium concentrations for municipal water supplies surveyed during this study.

A radium concentration of 0.68 pCi/l from the Erwin well north of Gallup (#9233) was the highest radium concentration for the municipal supplies. It appears that, on the whole, municipal water supplies in the Grants Mineral Belt area do not exceed 23% percent of the drinking water standard of 3.0 pCi/l.

Ten privately owned, potable water supplies were surveyed in the Murray Acres-Broadview Acres and other areas surrounding the United Nuclear-Homestate Partners mill. The highest radium concentration was 0.72 pCi/l

Table 7

Locations with Radium-226 in Excess of the PHS Drinking Water Standard[1]

Location Description	Radium-226[2] Dissolved pCi/1	Radium-226[2] Two Sigma pCi/1	Gross Alpha[2] Dissolved pCi/1	Gross Alpha[2] Two Sigma pCi/1	Remarks
#9121-Berryhill Section 5 Bluewater	6.3	0.1	12	14	Windmill Stock Feed Water
#9201-P. Harris Grants KM-46	3.6	0.1	110	40	Potable Water Supply
#9208-KM-43 Grants	4.0	0.1	49	35	Monitor Well
#9212-KM Seepage Return-Grants	4.9	0.1	112,000	3,000	Surface Water Sample
#9213-KM-B-2 Grants	6.6	0.1	8	32	Monitor Well
#9232-Jackpile-New Shop Well Paguate	3.7	0.08	18	13	Potable Water Supply

[1] PHS Drinking Water Standard, 1962, is 3.0 pCi/1 for Radium-226.

[2] Radium and gross alpha analysis by NEIC-Denver.

Table 8

Radium and Gross Alpha Concentrations for Municipal Water Supplies [1]

Location Description	Radium-226 Dissolved pCi/1	Radium-226 Two Sigma pCi/1	Gross Alpha Dissolved pCi/1	Gross Alpha Two Sigma pCi/1
#9112-Grants City Hall	0.42	0.02	19	13
#9116-Milan City Well #1	0.14	0.01	12	10
#9125-LDS Bluewater	0.22	0.01	8	10
#9137-Erwin Well Gallup	0.68	0.03	10	9
#9233-Municipal Well Paguate	0.18	0.02	2	4
#9141-Churchrock Village	0.12	0.01	3	7

[1] Radium and gross alpha results by NEIC-Denver.

at the Worthen well (#9107), and the lowest concentration was less than 0.05 pCi/l at the Schwagerty well (#9105). The average radium concentration for these 10 private wells was 0.26 pCi/l.

Six privately owned, potable water supplies in the Ambrosia Lake area contain 0.07 to 3.6 pCi/l. Of nine privately owned potable water supplies surveyed in the Grants-Bluewater area, the maximum radium concentration was 0.24 pCi/l. Only two privately owned wells were used solely as potable water supplies in the Gallup area. These were the Hassler (#9139) and Boardman (#9138) residences. The radium concentrations at these two locations were 0.22 and 0.64 pCi/l, respectively. The other 8 wells in the Gallup-Churchrock area were used mainly as stock water supplies and had an average radium concentration of 0.35 pCi/l.

Other Radionuclides

Table 9 entitled "Maximum Permissible Concentrations in Water" presents the unrestricted area - MPC and the population guide - MPC for selected radionuclides. The PHS Drinking Water Standard of 3 pCi/l for radium-226 is more restrictive than the population guide - MPC; therefore, the radium content evaluations were based on the 3 pCi/l drinking water standard. The other radionuclide content evaluations are based on the soluble MPC value since filtered ground-water samples were analyzed. The MPC values listed are from the NRC regulations which are also consistent with the NMEIA regulations (June 16, 1973).

Only 3 potable water supplies had complete isotopic uranium analysis - Wilcox (#9102), Enyart (#9133), and Dixie well (#9140). The highest reported results (for the Wilcox well) indicate less than 0.1%, 0.002%, and 0.06% of the population guide - MPC for uranium-234, uranium-235, and uranium-238, respectively.

Of all the potable water supplies analyzed for thorium-230, the Worthen well (#9107) had the highest concentration of 0.99 pCi/l. However, this is less than 0.15% of the population guide - MPC. The Meador well (#9113) had the highest thorium-232 content of 0.042 pCi/l and polonium-210 content of 2.3 pCi/l. These are 0.006% and 0.98% of the population guide - MPC, respectively.

Table 9

Maximum Permissible Concentrations in Water[1]
(Above Natural Background)

Radionuclide		Appendix B Table II, Column 2 (Unrestricted Areas) pCi/l	Population Guide[2] pCi/l
^{226}Ra	Soluble	30	10[+]
	Insoluble	30,000	10,000
^{228}Ra	Soluble	30	10
	Insoluble	30,000	10,000
^{210}Po	Soluble	700	233
	Insoluble	30,000	10,000
^{210}Pb	Soluble	100	33
	Insoluble	200,000	66,667
^{230}Th	Soluble	2,000	667
	Insoluble	30,000	10,000
^{232}Th	Soluble	2,000	667
	Insoluble	40,000	13,333
^{234}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{235}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{238}U	Soluble	40,000	13,333
	Insoluble	40,000	13,333
U-Natural			
	Soluble	30,000	10,000
	Insoluble	30,000	10,000

[1] 10CFR-Part 20--Standards for Protection Against Radiation--U.S.N.R.C. (April 30, 1975).

[2] Population Guide = 1/3 times Unrestricted Area MPC--Table II Values.

[+] A maximum permissible concentration of 3.33 pCi/l for ^{226}Ra is the Handbook 69 population guide (i.e., 1/30th of the HB69 continuous occupational exposure limits).

All 6 municipal water supplies were analyzed for thorium-230, thorium-232, and polonium-210. The highest thorium-230 content was for Grants (#9112), with 0.046 pCi/l (0.007% population guide - MPC). The highest thorium-232 content was for the Churchrock Village, with 0.016 pCi/l (0.002% of the population guide - MPC). The highest polonium-210 content was for the Municipal well at Paguate (#9233) with 0.39 pCi/l (0.17% of the population guide - MPC). In summary, exclusive of the radium-226 content, the highest isotopic uranium, thorium, and polonium-210 contents for any potable water supply in the Grants Mineral Belt area is less than 1.72% of the total radionuclide population guide - MPC. Exclusive of the Kerr-McGee seepage return sample (#9212) and the Anaconda injection well sample (#9107), the Worthen private well (#9107) had the highest gross alpha result of 2500 pCi/l. This gross alpha result underestimates the U-natural content reported as 9800 pCi/l (i.e., 98% of the allowable MPC). There are other examples of inconsistencies between gross alpha and natural uranium data. For example, samples #9102 and #9113 have gross alpha results of 3 pCi/l and 31 pCi/l, respectively. Comparable U-natural contents are 49 and 56 pCi/l (less than 0.56% of the U-natural MPC). In general, it appears that the uranium isotopes represent the greatest contributor of alpha activity. Considering the total radionuclide values to be the summation of uranium isotopes, thorium-230, thorium-232, and polonium-210 concentrations, the percentage of total radionuclides compared to gross alpha ranged from 31% (#9219) to 639% (#9102), exclusive of #9132 which has an extremely large discrepancy of results. Therefore, it appears that the gross alpha determinations have underestimated the natural uranium contents. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g., U-natural and polonium-210). Since the gross alpha results have such large error terms, no meaningful determinations of percentage of other radionuclides to gross alpha result can be implied.

With respect to the use of 15 pCi/l gross alpha (including uranium isotopes) as a "scan level" to indicate radium contents in excess of 5 pCi/l, only 2 locations fall in this category. Location #9121 had a gross alpha of 12 ± 14 pCi/l and a radium-226 content of 6.3 ± 0.1 pCi/l. Because of the large error term in the gross alpha determination (8 ± 32 pCi/l) for location #9213, this sample would be included in the group of locations having a gross alpha result greater than 15 pCi/1. This location had the highest radium-226 content of all the ground-water locations sampled (6.6 pCi/1). Of the 58 remaining ground-water locations with gross alpha results greater than 15 pCi/1 (range: <3 ± 13 to 2500 ± 200 pCi/1), the radium-226 contents ranged from 0.19 to 0.72 pCi/1, respectively. For ground-water samples with gross alpha greater than 15 pCi/1, the radium-226 concentration ranged from 0.06 to 6.6 pCi/1. Therefore, there appears to be no correlation between a gross alpha level of 15 pCi/1 (including uranium isotopes) and a radium-226 content of 5 pCi/1.

It is appropriate to conclude that for routine radiological monitoring of potable water supplies, isotopic uranium and thorium, polonium-210, and radium-228 analyses are not necessary. Accurate radium-226 and lead-210 analyses for each sample yield the most information for radiological evaluations of drinking water conditions.

REFERENCES CITED

Bond, A. L., 1975, N. Mexico Environmental Improvement Agency, Letter of February 14, 1975, to J. Thornhill, U. S. Environmental Protection Agency, Region VI, 2 p.

Chavez, E. A., 1961, Progress report on contamination of potable groundwater in the Grants-Bluewater area, Valencia County, New Mexico: N. Mexico State Engineer Office, Roswell, New Mexico.

Clark, D. A, 1974, State of the art - uranium, mining, milling, and refining industry: U.S. Environmental Protection Agency, Office of Research and Development, Corvallis, Oregon, Technology Series, Report No. EPA-660/2-74-038, 113 p.

Cooper, James B. and Edward C. John, 1968, Geology and groundwater occurrence in Southeastern McKinley County, New Mexico: N. Mexico State Engineer, Technical Report 35, prepared in cooperation with the U.S. Geological Survey, 108 p.

Dinwiddie, George A., W. A. Mourant, and J. A. Basler, 1966, Municipal water supplies and uses, Northwestern New Mexico: N. Mexico State Engineer Technical Report 29C, prepared in cooperation with the U.S. Geological Survey, 197 p.

Dudley, John, 1975, Water Quality Division, the N. Mexico State Health and Social Services Department, July 15 memorandum reply to Robert Kaufmann, Office of Radiation Programs, U.S. Environmental Protection Agency.

Dutton, C. E., 1885, Mount Taylor and the Zuni Plateau: in the Sixth Annual Report of the U.S. Geological Survey, 1884-85, p. 113-198.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw Hill, 534 p.

Fitch, A. J., 1959, October 9 letter from the Anaconda Company, Grants, New Mexico, to H. L. Price, Director, Division of Licensing and Regulations, U.S. Atomic Energy Commission, 16 p.

Gordon, Ellis D., 1961, Geology and ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico: N. Mexico State Engineer Technical Report 20, prepared in cooperation with the U.S. Geological Survey, 109 p.

Gray, W. E., 1975, Environmental Engineering, N. Mexico Operations, Uranium Division, The Anaconda Company, February 14 letter to Robert F. Kaufmann, U.S. Environmental Protection Agency, ORP, Las Vegas, Nevada, response to request for data.

Hilpert, Lowell S., 1963, Regional and local stratigraphy of uranium-bearing rocks: N. Mexico State Bureau of Mines and Min. Res. Memoir 15, p. 6-18.

Hiss, W., and T. Kelley, 1975, U.S. Geological Survey, WRD, Albuquerque, NM, February 14 written communication to John Dudley, New Mexico Environmental Improvement Agency.

John, Edward C., and S. W. West, 1963, Ground water in the Grants District: in N. Mexico State Bureau of Mines and Min. Res. Memoir 15, p. 219-221.

Keefer, D. H., 1974, Radiological Evaluation of Region VI National Pollution Discharge Elimination System Permits: unpublished briefing statement, U.S. Environmental Protection Agency, Region VI, Dallas, Texas, 9 p.

Kelley, Vincent C., ed., 1963, Tectonic setting: in N. Mexico State Bureau of Mines and Min. Res. Memoir 15, p. 19-20.

Kittel, Dale F., Vincent C. Kelley, and Paul E. Melancon, 1967, Uranium deposits of the Grants Region: in the New Mexico Geological Society Eighteenth Field Conference, Guidebook of the Defiance-Zuni-Mt. Taylor Region of Arizona and New Mexico, p. 173-183.

Lyford, F. P., 1975, U. S. Geological Survey, WRD, Albuquerque, NM, February 12 letter to John Dudley, New Mexico Environmental Improvement Agency.

Midwest Research Institute, 1975, A study of waste generation, treatment and disposal in the metals mining industry: Review draft of Final Report, Contract No. 68-01-2665 for Office of Solid Waste Management, U.S. Environmental Protection Agency, Washington, DC, 2 vol., 520 p.

National Academy of Sciences--National Academy of Engineering, 1972, A Report of the Committee on Water Quality Criteria: Environmental Studies Board, at the request of and funded by U. S. Environmental Protection Agency, 594 p.

National Bureau of Standards, 1959, Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure, Handbook 69, National Bureau of Standards, 95 p.

New Mexico Department of Public Health and U.S. Public Health Service, 1957, Report of an investigation of ground water pollution, Grants-Bluewater, New Mexico.

New Mexico Environmental Improvement Agency, 1973, Regulations for governing the health and eenvironmental aspects of radiation: New Mexico Environmental Improvement Agency, Santa Fe, New Mexico.

Public Health Service, U.S. Department of Health, Education, and Welfare, 1962, Drinking water standards--1962: PHS Publication No. 956, 61 p.

Stow, J. M., 1961, U.S. Geological Survey, WRD, Albuquerque, NM, April 14 letter to Eugene Chavez, State Engineer Office, Roswell, NM.

Tsivoglou, E. C., and R. L. O'Connell, 1962, Waste guide for the uranium milling industry: U.S. Department of Health, Education, and Welfare, Technical Report W62-12, Cincinnati, Ohio, 78 p.

U.S. Atomic Energy Commission, 1974, The Nuclear Industry: U.S. Atomic Energy Commission, Washington, D.C. WASH-1174-74, p. 39-45.

U.S. Environmental Protection Agency, 1974, Compliance monitoring procedures: Office of Enforcement, National Field Investigations Center, Denver, Colorado, 37 p.

U.S. Geological Survey, 1975, Unpublished data, New Mexico District.

U.S. Geological Survey, 1975, Unpublished data received via written communication from WRD, New Mexico District, Albuquerque, file number 08350500.

U.S. Nuclear Regulatory Commission, 1975, Standards for protection against radiation: 10CFR, Part 20 (April 30, 1975).

University of New Mexico, Bureau of Business Research, 1972, "New Mexico Statistical Abstract, 1972."

West, S. W., 1972, Disposal of uranium-mill effluent by well injection in the Grants area, Valencia County, New Mexico, U.S. Geological Survey Professional Paper 386-D, prepared in cooperation with the N. Mexico State Engineer office and the U.S. Atomic Energy Commission, 28 p.

Wright, J., 1974, New Mexico Environmental Improvement Agency, September 25 letter to G. J. Putnicki, U.S. Environmental Protection Agency, Region VI, Dallas, Texas.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. ORP/LV-75-4	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Technical Note: Summary-Ground Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico		5. REPORT DATE August 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Robert F. Kaufmann, Gregory G. Eadie, Charles R. Russell		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Radiation Programs Las Vegas Facility, P. O. Box 15027 Las Vegas, Nevada 89114		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same as above		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Ground-water contamination from uranium mining and milling results from the infiltration of radium-bearing mine, mill, and ion-exchange plant effluents. Radium, selenium, and nitrate were of most value as indicators of contamination. In recent years, mining has increased radium in mine effluents from several picocuries/liter (pCi/l) or less, to 100-150 pCi/l. The shallow aquifer in use in the vicinity of one mill was grossly contaminated with selenium, attributable to the mill tailings. Seepage from two other mill tailings ponds averaged 6[illegible]4 x 10^6 liters/year and, to date, has contributed an estimated 1.1 curies of radium to ground water. At one of these, an injection well was used to dispose of over 3400 x 10^6 liters of waste from 1960-1973. The wastes have not been properly monitored and have apparently migrated to more shallow, potable aquifers. No adverse impacts on municipal water quality in Paguate, Bluewater, Grants, Milan, and Gallup were observed. No correlation was found between gross alpha greater than 1[illegible] pCi/l and radium-226 in excess of 5 pCi/l. Company-sponsored monitoring and reporting programs do not describe the full impact of mining and milling operations on ground-water quality. Review by State and Federal agencies has generally been superficial. Improvements in these areas and additional ground-water sampling are recommended.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ground water, hydrogeology, uranium, water pollution, waste disposal, injection wells, wastes, natural radioactivity, radium, radiation hazards, radioactive wastes, mining, milling, tailings ponds.	Grants Mineral Belt New Mexico Uranium mining and milling.	Radioactive contaminants, Radioactive waste processing, waste disposal.

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 71
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 906/9-75-002	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Water Quality Impacts of Uranium Mining and Milling Activities		5. REPORT DATE September 1975
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) EPA, Region VI; ORP-Las Vegas; NEIC-Denver		8. PERFORMING ORGANIZATION REPORT NO. EPA 906/9-75-002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Protection Agency Region VI 1600 Patterson Street, Suite 1100 Dallas, Texas 75201		10. PROGRAM ELEMENT NO. 2FH192
		11. CONTRACT/GRANT NO. N/A
12. SPONSORING AGENCY NAME AND ADDRESS N/A		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Ground water in the study area is affected by mining and waste disposal associated with mining and milling. Contamination appears in close proximity to the mining and milling centers with the exception of more widespread selenium contamination of shallow ground water adjacent to the United Nuclear-Homestake Partners Mill. Contamination of municipally operated water supplies in the study area is not evident. Potable supplies derived from mine water at four industrial sites exceed applicable limits for selenium in drinking water. Three such systems exceed limits for Radium 226.

Recommendations developed are designed to assist the State in future regulation of uranium mining and milling for the purpose of safeguarding public health and insuring future environmental quality.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Uranium Radioisotopes Ground Water Water Quality Surface Water Potable Water	BT Radioisotopes RT Aquifers; water wells; water table RT Water Pollution NT Lagoons UF Drinking Water RT Public Health	

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)* N/A	21. NO. OF PAGES 188
	20. SECURITY CLASS *(This page)* N/A	22. PRICE

INSTRUCTIONS

1. **REPORT NUMBER**
Insert the EPA report number as it appears on the cover of the publication.

2. **LEAVE BLANK**

3. **RECIPIENTS ACCESSION NUMBER**
Reserved for use by each report recipient.

4. **TITLE AND SUBTITLE**
Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific title.

5. **REPORT DATE**
Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected *(e.g., date of issue, date of approvcl, date of preparation, etc.).*

6. **PERFORMING ORGANIZATION CODE**
Leave blank.

7. **AUTHOR(S)**
Give name(s) in conventional order *(John R. Doe, J. Robert Doe, etc.).* List author's affiliation if it differs from the performing organization.

8. **PERFORMING ORGANIZATION REPORT NUMBER**
Insert if performing organization wishes to assign this number.

9. **PERFORMING ORGANIZATION NAME AND ADDRESS**
Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hirearchy.

10. **PROGRAM ELEMENT NUMBER**
Use the program element number under which the report was prepared. Subordinate numbers may be included in parentheses.

11. **CONTRACT/GRANT NUMBER**
Insert contract or grant number under which report was prepared.

12. **SPONSORING AGENCY NAME AND ADDRESS**
Include ZIP code.

13. **TYPE OF REPORT AND PERIOD COVERED**
Indicate interim final, etc., and if applicable, dates covered.

14. **SPONSORING AGENCY CODE**
Leave blank.

15. **SUPPLEMENTARY NOTES**
Enter information not included elsewhere but useful, such as: Prepared in cooperation with, Translation of, Presented at conference of, To be published in, Supersedes, Supplements, etc.

16. **ABSTRACT**
Include a brief *(200 words or less)* factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **KEY WORDS AND DOCUMENT ANALYSIS**
(a) DESCRIPTORS - Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

(b) IDENTIFIERS AND OPEN-ENDED TERMS - Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.

(c) COSATI FIELD GROUP - Field and group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the Primary Field/Group assignment(s) will be specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **DISTRIBUTION STATEMENT**
Denote releasability to the public or limitation for reasons other than security for example "Release Unlimited." Cite any availability to the public, with address and price.

19. & 20. **SECURITY CLASSIFICATION**
DO NOT submit classified reports to the National Technical Information service.

21. **NUMBER OF PAGES**
Insert the total number of pages, including this one and unnumbered pages, but exclude distribution list, if any.

22. **PRICE**
Insert the price set by the National Technical Information Service or the Government Printing Office, if known.