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POLLUTION OF THE RIO GRANDE VALLEY-FILL AQUIFER

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INTRODUCTION

Excluding numerous private water supply wells, more than 95 percent of all community water-supply systems* in New Mexico rely totally upon ground water (S. Pierce, personal commun., 1981). The Rio Grande valley-fill aquifer (Bjorklund and Maxwell, 1961) is the only source of drinking water for the Albuquerque municipal system (Cummins, 1981). In the Albuquerque area the saturated thickness of fresh ground water can exceed 900 m (U.S. Geological Survey, 1972).

GROUNDWATER POLLUTION

For the purpose of this report, ground-water pollution is defined as a result of human activity involving either a significant increase in concentration of any dissolved constituent above ambient levels, the introduction of fluids immiscible with water, or the presence of pathogenic microbes. Polluted ground water does not necessarily exceed water-quality standards. Aquifer pollution often remains undetected until appearing in a well. Tastes and odors can reveal gross pollution; trace levels (<20 µg/l) generally do not cause suspicious organoleptic effects.

The relatively poor quality of shallow (<30-m-deep) ground water has been recognized by Bjorklund and Maxwell (1961) and by Wilson and others (1977). This paper does not attempt to distinguish between mineralization caused by phreatophyte flora versus that caused by irrigation water seepage.

Wilson and others (1977) attributed widespread, generally low-level pollution in the Albuquerque area to numerous on-site disposal systems (e.g., septic tanks). These findings are supported by Heggen and others (1979) who identified several regions of anaerobic contamination in the North valley, apparently due to a high concentration of organic matter from disposal systems. Both studies indicate that nitrate levels are generally below the health standard of 10 mg/l NO₃-N, but Heggen and others (1979) detected sulfide concentrations in excess of the European health standard of 0.05 mg/l in 80 percent of the wells sampled.

Regional pollution of the Rio Grande with fecal coliform bacteria is suggested by the New Mexico Water Quality Control Commission (1976), here referred to as WQCC. Numerous instances of coliform contamination of ground water appear to be related to local unsanitary conditions (i.e., locations where a well and/or on-site disposal system do not meet modern construction criteria) rather than regional microbial pollution (Wilson and others, 1977). A 1971 study concluded that while the population of Albuquerque's South valley area was 0.03 percent of the State population, over 10 percent of all cases of hepatitis, shigella, and salmonella statewide were reported in the South valley (New Mexico Water Quality Control Commission, 1976). Regional microbial ground-water pollution cannot be concluded due to variations in personal hygiene, medical reporting practices, and well and/or on-site disposal system construction methods.

The well-numbering system used by the New Mexico Water Resources Division (Bjorklund and Maxwell, 1961) is used in this report to locate wells and areas of concern (e.g., 9N.3E.4). Some areas of concern span two or more sections (e.g., 9N.3E.4 and 5).

Nitrate Pollution

For more than 20 years, nitrate levels exceeding the health standard (e.g., 2,130 mg/l NO₃-N) have been known to occur in the Mountainview area, where the depth to ground water ranges from 3 to 9 m. NO₃-N levels of 452 mg/l and 305 mg/l were recently measured in well water samples from Mountainview (Environmental Improvement Division, 1982). A 5.5-month-old male infant residing in Mountainview was hospitalized in June, 1980 for two episodes of apnea and bradycardia. His methemoglobin level was measured as 14.9 percent of total hemoglobin (the normal range is considered to be 0.4-1.5 percent). A NO₃-N level of 261 mg/l was measured in his family's well, but they apparently obtained drinking water from their neighbor's well containing 47 mg/l NO₃-N (Castle and Lapham, 1981).

High nitrate levels have also been reported in the Pajarito community (Wilson and others, 1977), in the Tijeras drainage system at 9N.3E.11.241 (Bjorklund and Maxwell, 1961), and at 10N.4. 1/2E (Titus, 1980), but the highest documented levels occur in Mountainview. Hypotheses on the origin(s) of the extraordinarily high levels in Mountainview await confirmation.

Septic tanks, agricultural facilities, dumpsites, nitrate-contaminated surface water, naturally occurring sources (e.g., Paleozoic strata), and a hypothetical "closed-loop" hydraulic system wherein a ground-water mound due to seepage from nearby drains and canals causes nitrogenous ground water to be locally recycled and concentrated, have been considered by one or more investigators of various aspects of the nitrate problem (Wilson and others, 1977; Hines, 1981). Septic-tank pollution is likely in some areas (Titus, 1980).

Other locations of nitrate pollution

The following information is taken from Environmental Improvement Division (1982), here referred to as EID, studies.

9N.3E.7: NO₃-N levels up to 55.3 mg/l were measured in the Rio Grande alluvial aquifer in the vicinity of sludge drying beds at sewage treatment plant No. 2.

9N.3E.31.4: Wash water from the cleaning of cattle pens appears to have elevated NO₃-N levels from <1 mg/l to 7 mg/l.

10N.3E.29.3: NO₃-N levels up to 501 mg/l have been measured in ground water sampled from pits excavated into the Rio Grande alluvial aquifer in an area hydraulically down-gradient from structures at sewage treatment plant No. 1.

13N.3E.36.2: A level of 11.7 mg/l NO₃-N was measured in water from a well at an agricultural facility; the cause is unknown.

Pollution by Organic Compounds

Relative to classical health parameters such as nitrate, quantification of specific organic solutes often involves newly developed technology and requires meticulous quality-control procedures (Pettyjohn and others, 1981; American Society for Testing and Materials, 1981). Important observations, however, can sometimes be made by comparing the chro-

*A community water-supply system either serves at least 15 connections or serves at least 25 or more individuals at least 60 days per year.

matographic signals of complex samples without identifying each specific organic compound. In a presentation of methods for estimating the number of unseen (but potentially observable) organic pollutants in the aquatic environment, Janardan and Schaeffer (1981) point out that in general, for a complex water sample containing a large number of distinct compounds, only a fraction of the compounds potentially identifiable by a given method are actually identified. When an organic compound is detected in a water sample, two key questions must be asked.

1. Is that compound a true water-sample contaminant? Laboratory contamination is troublesome particularly with dichloromethane. Gas chromatograph-mass spectrometer (GCMS) analyses produce several "best fits" of the signal of a sample contaminant with the signals of compounds in the analyst's computer library. Millions of organic chemicals have been identified, but GCMS libraries, such as that used by the New Mexico Scientific Laboratory Division, contain data for about 32,000 chemicals. The presence in water, within the limits of detection, of common organics such as benzene is relatively easily confirmed. A GCMS computer often identifies rather exotic contaminants for which standards are not readily available; some degree of analytical misidentification is probably unavailable.

2. Is that compound a true water-source contaminant? Improperly cleaned sample vessels and improper sampling procedures may cause sample contamination. Contaminants not present in a water source (e.g., an aquifer) can be introduced by such features as plumbing materials. The loss of water-source contaminants must also be considered. The quantity of volatile organics lost by outgassing, for example, can greatly depend on sample extraction methods (e.g., a suction lift pump versus a bailing device that preserves in-situ hydrostatic pressure).

Hydrocarbon fuel oils such as gasoline and diesel and many one- or two-carbon polychlorinated compounds are somewhat mobile in the subsurface and are quite capable of polluting ground water (American Petroleum Institute, 1980; Council on Environmental Quality, 1981). Steel underground storage tanks have a reputation of leaking gasoline; fiberglass tanks are now commonly used. Some companies, such as Chevron U.S.A., Inc., are undertaking commendable programs of pressure testing tanks to identify and resolve potential problems.

Locations of organic compound pollution

The following locations are summarized from Environmental Improvement Division (1982) research.

4N.2E.29: This site is located immediately northwest of the intersection of N.M. State Roads 47 and 346. Ground water sampled from pits excavated into the water table next to a now inoperative gas station was reportedly polluted with gasoline.

5N.2E.18.4: Diesel-fueling operations have been conducted at this site since the early 1950's. Efforts to control fuel spillage include the installation during 1970-72 of fuel nozzles with automatic shut off feature to prevent tank overflow and the installation in 1978 of spill collector pans. The 2-3 m deep water table has been polluted with fuel at least since 1975. Several private domestic wells have been impacted. A trench —100 m long was dug to —0.5 m below the water table. The trench was backfilled with gravel. A vertical, —1-m-diameter perforated pipe is located midway in the trench. A pump removing oil from the water surface began operating in January, 1980 and has recovered more than 400,000 l (liters) of diesel fuel. Polychlorinated biphenyls (PCBs; 60 percent Cl) at <0.1 p,g/l and 1,1,1-trichloroethane at <1.0 p,g/l were detected in water sampled from a private domestic well in October, 1980. PCB levels of 3.0 mg/kg (48 percent Cl) and 0.3 mg/kg (60 percent Cl) were detected in soil from a nearby industrial facility. The mechanism of contamination in this case is unknown, but in a transformer-oil spill case study Roberts and others (1982) argue that the

most likely mechanism for the observed vertical and lateral migration of large quantities of PCBs is movement of the oily liquid. However, a dissolved aqueous phase and an adsorbed phase exist at many locations in the ground-water system.

7N.2E.28.344: A domestic well located —30 m southwest of a gas station reportedly became polluted with gasoline in 1973-74. A pit excavated into the shallow water table between the well and the now inoperative gas station also reportedly contained polluted ground water.

9N.2E.12.2321: After the detection of gasoline odor, an old storage tank at a recently rebuilt gas station was excavated. Gasoline seeped into the bottom of the pit. In October, 1981, explosive concentrations of gasoline vapor were detected <1 m below land surface east and north of the station and to the west around a private house. Generally, lower vapor levels were detected south of the station. Gasoline has been recovered from the pit and from a cesspool near the house. Company records indicate a loss of perhaps 4,000 l of unleaded gasoline from the old tank. Inventory data have not been obtained from the former operator.

9N.2E.13.121: Gasoline on top of ground water was discovered in a construction-related excavation in 1980. Dewatering processes created unusual waste-disposal problems when the contaminated water could not be discharged to a nearby canal. A leaky storage tank at a nearby gas station was identified as the source.

9N.3E.4 and 5; 10N.3E.32 and 33: Tastes and odors of organic contaminants were evident in water from a supply well at a chemical-handling facility (well 9N.3E.5.222) in 1978. In addition to the volatiles listed in Table 1, numerous other organics (including acids, ethers, ketones, aliphatic hydrocarbons, and polycyclic compounds) have been detected in one or more of four analyses. In 1980 three municipal supply

Table 1. Worst-case examples of organic contaminants in the South valley area of Albuquerque. These data do not reflect the analytical problems experienced with contaminant levels of —20 tigl or less. Well A at 9N.3E.5.222 has been sampled 4 times during 1979 to 1981. Well B, municipal supply well San Jose No. 6 at JON.3E.32.414, has been sampled 7 times during 1979 to 1982; 2 samples were sent to several different laboratories. The data for waste water were collected from 2 different facilities. X= contaminant identified but not quantified; N=contaminant specifically looked for but not detected; and all concentrations are micrograms per liter (p,g/l).

Contaminant and WQCC Human-Health Standard for Ground Water	Well A	Well B	Waste Water	
Benzene	10	105	X	8,480
methyl-	15,000	2	X	19,800
dimethyl-		X	N	16,990
ethyl-		N	N	3,700
Methane				
dichloro-		18	4	200
trichloro-		N	3	
tetrachloro-	10	N	1	
Ethane				
1,1-dichloro-		N	13	
1,2-dichloro-	20	360	4	650
1,1,1-trichloro-		2	<1	14
Ethene				
1,1-dichloro-	5	N	11	
1,2-trans-dichloro-		N	<1	
trichloro-	100	N	21	23
tetrachloro-	200	X	16	160

wells in the area (e.g., San Jose No. 6 in Table 1) were shut down after the detection of several volatile contaminants of health concern. One city well was put back to use in 1981 after subsequent analyses did not detect volatile organics.

The EID is conducting a drilling and monitoring program funded by the U.S. Environmental Protection Agency to determine the source(s) and extent of pollution. The study area as described and mapped by Lambert (1968) extends eastward from floodplain alluvium through alluvial-fan and fan-apron deposits along the inner-valley margin and into the Upper Buff formation of the Santa Fe Group; the depth to ground water in the area of known pollution ranges from -6 to 29 m. This is a prototype study for the EID. Several monitoring techniques (described below) are being tested in this study. Locating vadose-zone pollution is very important for identifying the source(s) unless contaminants were injected into the aquifer (e.g., by means of inadvertent backflow siphonage into a well). Vadose-zone soil samples are collected in oblong glass chambers, with teflon stopcocks on each end, from which gases are purged for volatile organics GCMS analysis. To reduce the chances of introducing organic contaminants during well installation, stainless-steel well screens are driven below the drill bit of a hollow-stem auger. Samples are extracted with a bailer.

An inventory of potential sources reveals that many organic compounds, sometimes accompanied by acids and bases, have entered the subsurface at one or more facilities in the area. Some wastes were exposed to ultraviolet light (i.e., sunlight) before entering the subsurface. The question of whether biochemical- or physicochemical-pollutant transformations have occurred must be considered. It is well established that some organic pollutants are anaerobically biodegradable in soil and/or ground water (Leenheer and others, 1976; Witt and McKinney, 1981; Sykes and others, 1982). Kobayashi and Rittmann (1982) present evidence that many organics of health concern can be attacked by microbes (e.g., soil bacteria). McConnell and others (1975) report the dehydrochlorination of 1,1,1-trichloroethane in sea water.

Results of the EID study strongly suggest multiple pollution sources. Diesel fuel floating on water, but no chlorinated compounds, were detected in analyses of sediment, water, and oil at depths of -5-6 m at 10N.3E.32.4143. The source(s) of the chlorinated aliphatics in San Jose well No. 6, which is reported to be >270 m deep, remain undetermined. Regulatory efforts are underway to control discharges of organic contaminants in the study area.

11N.3E.10.41 and 43: In November, 1981 a well driller reported gasoline contamination of a well penetrating a 6-m-deep water table. Additionally, Wilson and others (1979) report a well at an ice plant being contaminated by a leaking tank at a gas station at an undisclosed location in Albuquerque. It is not known whether this case is the same as one of those described above.

HEALTH EFFECTS AND REGULATIONS

Ground-water quality regulations authorized by the New Mexico Water Quality Act became effective in 1977. The purpose of these regulations controlling discharges onto or below the surface of the ground is to protect all ground water of the State of New Mexico which has an existing concentration of 10,000 mg/l or less total dissolved solids, for present and potential future use as domestic and agricultural water supply, and to protect those segments of surface waters which are gaining because of ground-water inflow, for uses designated in the New Mexico Water Quality Standards (New Mexico Water Quality Control Commission, 1982).

Nitrate

Two potential health hazards are related to the consumption of water containing large concentrations of nitrate (or nitrite): (1) induction of methemoglobinemia, particularly in infants, and (2) potential formation

of carcinogenic nitrosamines. Nitrate toxicity occurs as a result of its reduction to nitrite. A series of steps is involved by which nitrate present in water or food is converted by bacterial action to nitrite. This process can take place prior to ingestion, in the salivary glands, or in the stomach.

Nitrite acts in the blood to oxidize hemoglobin (the oxygen-carrying molecule) to methemoglobin, which does not provide oxygen to the tissues. In severe cases the victim's nailbeds and lips are cyanotic. Healthy adults are reported to be able to consume large quantities of nitrate in drinking water without developing methemoglobinemia, which is almost always seen in infants rather than adults. This increased susceptibility of infants has been attributed to high intake per unit weight, to the presence of nitrate-reducing bacteria in the upper gastrointestinal tract, to the condition of the mucosa, and to greater ease of oxidation of fetal hemoglobin. Gastric pH greater than 4 is conducive to the growth of nitrate-reducing bacteria. Such gastric conditions are likely to occur with infants, who are prone to upset stomachs and achlorhydria. From the viewpoint of induction of methemoglobinemia, the maximum concentration of nitrate in water exhibiting no observed adverse health effects is close to the standard of 10 mg/l as nitrogen, established by the WQCC.

The other health hazard associated with nitrate in drinking water, that it may act as a procarcinogen, is much more speculative. Following the conversion of nitrate to nitrite, the nitrite can then react with other substances, such as amines, to form N-nitroso compounds. Most N-nitroso compounds are carcinogenic at high doses in animal tests. There is some evidence to support the possible etiologic role of nitrates in the development of gastric and esophageal cancer; however, this relationship is undocumented at present. There is no apparent association between dietary nitrates and other cancers.

Organic Compounds

Most of the numerical standards adopted by the WQCC for organic ground-water contaminants were developed based upon cancer risks which would result from drinking polluted ground water over a long period of time. WQCC regulations also contain a narrative definition of "toxic pollutant" which includes a list of >70 organic compounds identified as "potential" toxic pollutants. A potential toxic pollutant becomes a toxic pollutant if it causes, for example, an additional lifetime cancer risk greater than one additional cancer per 100,000 exposed persons.

Human toxicological data for benzene are relatively good. Benzene has been causally linked to leukemia, aplastic anemia, and other conditions of the blood and bone marrow in humans. The WQCC ground-water standard of 10 p,g/l represents a lifetime carcinogenic risk of about one additional cancer per 100,000 exposed persons (Zalma, 1981).

Due to the absence of any literature supportive of any carcinogenicity of pure toluene, the WQCC ground-water standard of 15 mg/l is based upon noncarcinogenic toxicity considerations (Zalma, 1981). There is some evidence that toluene at very high doses causes increased chromosome breaks in rats, but more studies need to be done (Puck, 1981).

The WQCC ground-water standard of 1 lig/l of PCBs is based upon carcinogenic risks, from the ingestion of contaminated ground water, for which bioconcentration in edible aquatic organisms is not a factor (Zalma, 1981). Should PCB-laden ground water discharge to surface water in which edible aquatic organisms reside, WQCC stream standards may apply (New Mexico Water Quality Control Commission, 1981).

^tModified from Castle and Lapham, 1981, p. 2, 3.

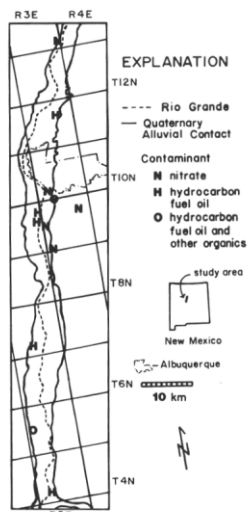


Figure 1. Locations of ground-water pollution and anomalous ground-water quality in the Rio Grande valley-fill aquifer. The base map, including the Quaternary alluvium contact, is from Dane and Bachman (1965); the township and range grid was projected into unsectioned areas. Regional pollution is not shown.

Carbon tetrachloride is a proven liver toxin and a proven hepatocellular carcinogenic agent. The linearized multi-staged extrapolation from observable high-dose responses to hypothetical low-dose responses, a reasonable assumption for CCl_4 , was used to calculate the WQCC ground-water standard of 10 figil (Zalma, 1981).

Human toxicological data for 1,2-dichloroethane, 1,1-dichloroethene, trichloroethene, and tetrachloroethene are not as good. The principal health concern of these compounds or of their metabolic by-products is carcinogenicity involving the liver or, in the case of 1,1-dichloroethene, the kidney (Zalma, 1981).

CONCLUSIONS

It is not surprising that most cases of ground-water pollution are located km away from the Rio Grande where the depth to ground water is relatively shallow (fig. 1). In several cases the shallow water table was intercepted by surface excavations. As exemplified by this paper, the EID's statewide inventory of ground-water pollution and anomalous water quality has grown considerably since its creation during the surface impoundment assessment study (Boyer and others, 1980). The EID was recently granted federal funds to continue this work and to provide more detail to this inventory. The study will focus on but will not be limited to nitrate, hydrocarbon fuel oils, and other toxic organics; several sites will be selected for intensive field study. Interstate disputes over water rights, such as that underway between the City of El Paso, Texas and the State of New Mexico, underscore the need to protect the quality of precious drinking-water aquifers.

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REFERENCES

- American Petroleum Institute, 1980, Underground spill cleanup manual: American Petroleum Institute Publication 1625, p. 4-11.
 American Society for Testing and Materials, 1981, Annual book of standards part 31-water: American Society for Testing and Materials, p. 639-833.
 Bjorklund, L. J. and Maxwell, B. W., 1961, Availability of ground water in McQUILLAN

- the Albuquerque area, Bernalillo and Sandoval Counties, New Mexico: New Mexico State Engineer Technical Report 21, 117 p.
 Boyer, D. G., McQuillan, D., and Goad, M. S., 1980, New Mexico surface impoundment assessment: Water Pollution Control Bureau, New Mexico Environmental Improvement Division, 146 p.
 Castle, S. P. and Lapham, S. C., 1981, The investigation of elevated nitrate levels in private well water in the Mountainview area of New Mexico: New Mexico Health and Environment Department Epidemiology Section Memorandum of February 9, 1981, 6 p.
 Council on Environmental Quality, 1981, Contamination of ground water by toxic organic chemicals: Council on Environmental Quality, p. 4-5, 36-39.
 Cummins, S., 1981, Testimony before the New Mexico Water Quality Control Commission: Transcript of public hearing on proposed regulation amendments, July 14 and 15, 1981, p. 386.
 Dane, C. H. and Bachman, G. O., 1965, Geologic map of New Mexico: U.S. Geological Survey, 1:500,000.
 Environmental Improvement Division, 1982, Inventory of ground-water pollution and anomalous water quality in New Mexico, updated through May 10, 1982: New Mexico Health and Environment Department.
 Heggen, R. J., Thomson, B. M., Matthews, J. R., and Tefera, A., 1979, Ground-water quality study, City of Albuquerque, North valley: Bureau of Engineering Research, College of Engineering, University of New Mexico, report n. CE-812-1, 34 p.
 Hines, W. G., 1981, Preliminary evaluation of nitrate pollution in shallow ground water of the Mountainview community, Bernalillo County, New Mexico: Report submitted to the Environmental Improvement Division, 12 p.
 Janardan, K. G. and Schaeffer, D. J., 1981, Methods for estimating the number of identifiable organic pollutants in the aquatic environment: Water Resources Research, v. 17, p. 243-249.
 Kobayashi, H. and Rittman, B. E., 1982, Microbial removal of hazardous organic compounds: Environmental Science and Technology, v. 16, p. 170A-183A.
 Lambert, P. W., 1968, Quaternary stratigraphy of the Albuquerque area, New Mexico (Ph.D. thesis): University of New Mexico, Albuquerque, 329 p.
 Leenheer, J. A., Malcolm, R. L., and White, W. R., 1976, Physical, chemical, and biological aspects of subsurface organic waste injection near Wilmington, North Carolina: U.S. Geological Survey Professional Paper 987, p. 41.
 McConnell, G., Ferguson, D. M., and Pearson, C. R., 1975, Chlorinated hydrocarbons and the environment: Endeavour, v. 34, p. 17.
 New Mexico Water Quality Control Commission, 1976, Middle Rio Grande basin plan: New Mexico Water Quality Control Commission, p. V-8 to V-29.
 , 1981, Water quality standards for interstate and intrastate streams in New Mexico as amended through June 4, 1981: New Mexico Water Quality Control Commission, 40 p.
 , 1982, Regulations as amended through January 29, 1982: New Mexico Water Quality Control Commission, 36 p.
 Pettyjohn, W. A., Dunlap, W. J., Cosby, R., and Keeley, J. W., 1981, Sampling ground water for organic contaminants: Ground Water, v. 19, p. 180-189.
 Puck, S., 1981, Testimony before the New Mexico Water Quality Control Commission: Transcript of public hearing on proposed regulation amendments, July 14 and 15, 1981, p. 220.
 Roberts, J. R., Cherry, J. A., and Schwartz, F. W., 1982, A case study of a chemical spill-polychlorinated biphenyls (PCBs): 1. History, distribution and surface translocation: EOS, v. 63, p. 168.
 Sykes, J. F., Soyupak, S., and Farquhar, 1982, Modeling of leachate organic migration and attenuation in groundwaters below sanitary landfills: Water Resources Research, v. 18, p. 135-145.
 Titus, F. B., 1980, Ground water in the Sandia and Northern Manzano mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 5, p. 37-39.
 United States Geological Survey, 1972, Map showing estimated thickness of aquifers that contain fresh ground water in New Mexico: U.S. Geological Survey Open-file map.
 Wilson, L., Jenkins, D., Anderson, S., Classen, A., Hanna, D., and Diebold, C., 1977, Technical reference document for Albuquerque wastewater treatment facilities: report submitted to Albuquerque, New Mexico, project n. C-35-1020-01, part D, 155 p.
 Wilson, L., Anderson, S. T., Jenkins, D. N., and Christiano, C., 1979, Program for the statewide monitoring of ground-water quality in New Mexico: Final report submitted to the Environmental Improvement Division, p. 11-8.
 Witt, E. R. and McKinney, C. H., 1981, Anaerobic biological activity in Bishop Plant subsoil: Ground-water contamination study, submitted to Texas Department of Water Resources by Underground Resource Management, Inc., p. C-108 to C-121.
 Zalma, V. M., 1981, Testimony before the New Mexico Water Quality Control Commission: Transcript of public hearing on proposed regulation amendments, July 14 and 15, 1981.