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Christine E. Bough

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Abstract

This is a case study of the groundwater quality near the McDowell Sanitary Landfill in Phelps County, Missouri. The landfill is located in section 21 of T37N R8W off of Missouri State Highway CC. This landfill is a near surface solid waste disposal facility above the groundwater table located in an abandoned area of a rock quarry. The thickness, lithology, and structure of the material beneath the landfill, and the design of the landfill itself, will influence the time of contaminant transport and degree of modification in the event that leachate escapes the landfill. Among the more important topographic features in Phelps County, Missouri, is the widespread occurrence of karst features, which results from solution and erosion of limestone and dolomite bedrock. Karst features in Phelps County pose a threat to groundwater contamination because of the potential large capacity for open channel flow. There are two major aquifers in Phelps County that could be contamination by a leaking landfill. These are the Roubidoux Sandstone and the Gunter Member of the Gasconade Dolomite. The Roubidoux Sandstone is the shallowest aquifer and thus is the one that has the highest probability of being contaminated. Based on our Atomic Absorption analysis for calcium, magnesium, sodium, potassium, total iron, and chloride, it was found that the groundwater is not contaminated in Phelps County near the McDowell Sanitary Landfill. These results show that if landfills are properly designed for each hydrogeologic setting, groundwater contamination can be avoided.

Introduction

This report describes the investigation of groundwater quality near the McDowell Sanitary Landfill. The landfill is owned and operated by the Phelps County Landfill Board, which was organized in August 1973 and is comprised of the chief elected official of each city in Phelps County, in addition to the presiding Judge of the Phelps County Court.

Landfills are surface or near surface solid waste disposal facilities above the groundwater table. Soluble substances in the waste material may be gradually removed by solution in percolating waters that originate from precipitation, surface runoff, or addition of fluids to the landfill. These soluble substances, known as leachate, often form a liquid sometimes containing heavy metals and organics. The thickness and character of the unconsolidated deposits beneath a landfill, and the design of the landfill itself, influence the time of waste transport and degree of modification before leachate reaches the water table. Both bedrock lithology and structure may also influence the travel time and chemistry of the leachate.

Leachate reaching the water table tends to maintain its chemical integrity with dilution occurring mainly where it contacts the groundwater. If the leachate escapes the landfill it will move in the direction of groundwater flow as a plume whose shape is determined by the flow characteristics of the aquifer, a geologic unit that supplies water for wells and springs.

This report discusses the general characteristics of the physiography, geology, and groundwater near the landfill site. It also discusses specific details on the groundwater quality of the study area.

Site Description

Location

The landfill is located in Phelps County off of Missouri State Highway CC approximately 2 miles west of U.S. Highway 63 in section 21 T37N R8W. The site is in an abandoned area of a rock quarry on the William McDowell property. The site location is shown in figure 1 below.

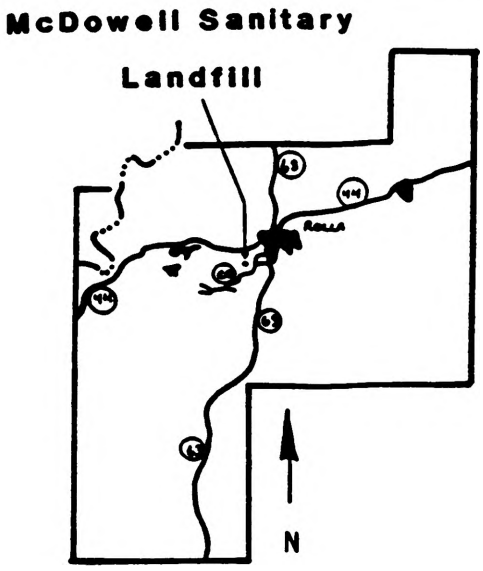

Figure 1. Map of Phelps County Showing Location of Landfill

Physiography

Phelps County lies in the northeastern part of the Salem Plateau section of the Ozark Plateau physiographic province just west of the divide between the Gasconade and Meramec River Basins. The Salem Plateau is underlain by essentially flat Cambrian and Ordovician sandstones, limestones, and dolomites; therefore, the topography of the area is controlled by the stratigraphy.

Topography and Drainage

Among the more important topographic features in the Ozark Region of Missouri is the widespread occurrence of karst features, which result from solution and erosion of limestone and dolomite bedrock. The term karst designates areas characterized by thin clayey soils and bedrock, sinkholes connecting surface and groundwater, caverns and small openings serving as underground conduits, springs bringing groundwater to the land surface, and losing streams transporting water underground. These features form a unique topography with very irregular surface and subsurface drainage patterns. There are no significant springs, caves, or sinkholes in the area that would effect the landfill.

The entire eastern part of Phelps County is deeply dissected by short, abrupt, deeply cut stream channels separated by narrow ridges. The ridge tops are nearly level, continuous, and remarkably uniform in shape. They are covered by residual materials to depths of 30 feet or more. The lowest point in the area, 640 feet above sea level, is at Boulware Ford in the northwest corner of the County, and the highest point, 1244 feet, is Pilot Knob in the southeast quarter. Therefore, the maximum relief of the area is 596 feet. The elevation at the landfill is approximately 980 feet with a slightly rolling topography.

The surface drainage of the area empties into the Gasconade and the Meramec River Basins. The Little Piney Creek, gathering the largest percentage of the Phelps County drainage, flows from the southeastern corner north to the center of Phelps County and then turning west to join the Gasconade River. Several smaller creeks collect the drainage of the southern and eastern parts of the area and flow into the Little Piney Creek. The basin of the Little Piney creek is limited on the north by Pea Ridge which crosses the Phelps County from Rolla to the Gasconade River. The surface drainage from nearby points that are higher than the rim of the landfill was routed around the landfill by diversion ditches to the natural drainageway lying to southwest of the landfill to prevent ponding in the pit. There are no significant creeks or lakes in the area that would have an affect on the landfill.

Climate

Phelps County has a humid climate with relatively mild winters and warm summers. The annual average temperature is 56.2 degrees Fahrenheit. The average temperature for July is 77.8 degrees Fahrenheit and for January is 32.9 degrees Fahrenheit. The average annual precipitation is 39.7 inches per year. See figure 2, a graph of average monthly precipitation values.

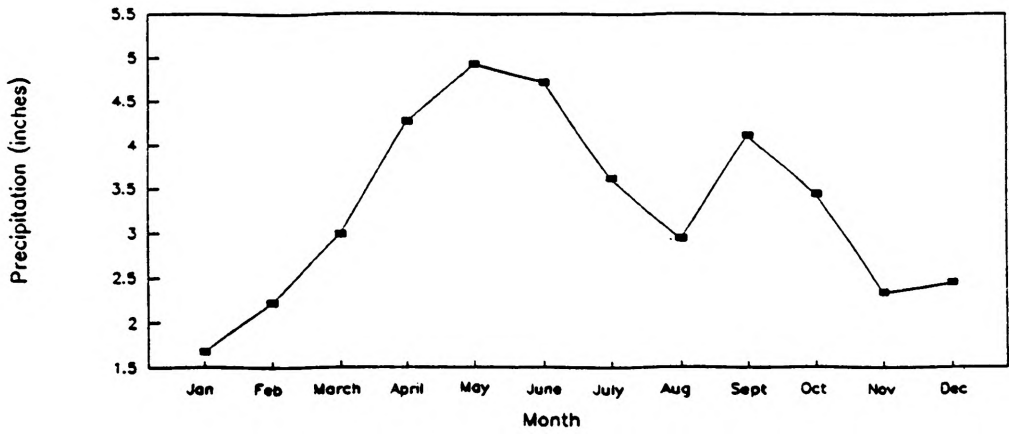

Figure 2. Average Monthly Precipitation (National Weather Service)

Geology

Stratigraphy

All of the stratigraphic units that outcrop in Phelps County are part of the Canadian Series of the Ordovician System. The strata of the Canadian Series in Central Missouri are composed predominantly of arenaceous and cherty dolomite and sandstone. The stratigraphic units will be discussed from youngest (the Jefferson City Formation) to oldest (the Gasconade Formation). See figure 3 for the stratigraphic column, which is a graphical representation of the geologic units discussed here.

The Jefferson City Formation is composed of crystalline dolomite with chert as nodules and lenses. Green shale partings and sand are present along bedding planes but are not subordinate. The dolomite beds are thin except for one , the "Quarry Ledge", which is about 20 feet thick. Much of the dolomite is earthy and weathers to a buff stone locally called, "cotton rock". The Jefferson City forms the tops of the uplands in the Rolla area. It has a thickness ranging from 125 feet to 350 feet. The landfill is located in the Jefferson City Formation.

The Roubidoux Formation consists of three well developed sandstone beds with inter-bedded chert and dolomite. The sandstones tend to form red-stained outcrops and the dolomite dissolves away when weathered. The Roubidoux forms a pronounced upland surface. The thickness of the Roubidoux ranges form 100 to 250 feet.

The Gasconade formation consists of three units: an upper unit of coarsely crystalline dolomite with very small amounts of chert, a middle unit characterized by a cherty horizon, and the lower unit consisting of a basal sandstone, the Gunter Member. The upper unit tends to be cavernous and is readily leached by groundwater. The steep walled valleys of the Gasconade and the Little Piney rivers are developed in this upper portion of the formation. The Gunter Member varies from a sandy dolomite to a true sandstone. The average thickness of the Gasconade formation is 300 feet.

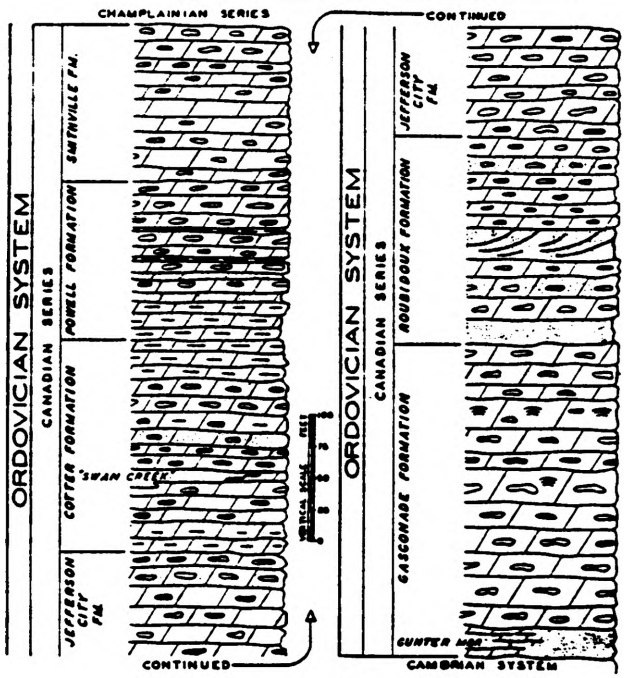

Figure 3. Geologic Units in Phelps County (Howe, 1961).

Structure

Phelps County lies within the stable Mid-Continent area. The dominant structural feature is the Ozark Uplift that is responsible for the uplift of the St. Francais Mountains in southeastern Missouri. There have been at least six mild uplifts since the time of the St. Francais Mountains which are shown by unconformities in the stratigraphic record. The uplift is asymmetrical and dips steeply on the southeast and east into the Illinois Basin.

There has been a considerable amount of faulting and folding associated with the Ozark uplift. However, the strata in Phelps County is relatively flat with only minor faulting occurring. The largest area of faulting occurs in a belt about two miles south of Newburg, Missouri. These faults trend in a northwest - southeast direction. These faults do not appear to affect the hydrology of Phelps County.

A test hole drilled in April 1980 revealed a 17 foot layer of dense dolomite below the floor of the proposed landfill. This thick layer of rock suggests that the landfill should not cause any harmful fracturing to occur that would result in the escape of leachate into the groundwater.

Investigation of Groundwater Quality

Groundwater

Aquifer Characteristics

There are two principle fresh-water aquifers that yield a dependable supply of water in Phelps County. They are the Roubidoux Formation and the Gasconade Formation. See figure 4 for the relationship of the aquifers. The groundwater reservoir in this area consists of a section of more than 2000 feet of Cambrian and Ordovician dolomite and sandstone. The aquifers will be discussed from youngest to oldest.

System	Series	Formation	Thickness	Lithology	Hydrogeology
Ordovician	Canadian	Cotter Dolomite	55–355	Cherty dolomite	This unit acts as a major aquifer in this area.
		Jefferson City	125–350	Dolomite with chert lenses	
		Roubidoux	100–250	Sandstone and cherty dolomite	Water from this aquifer is a calcium–magnesium bicarbonate type
		Upper Gasconade	40–100	Crystalline dolomite and chert	
		Lower Gasconade Gunter Member	235–320 25–50	Quartzose Sandstone	Wells open to the total thickness

Figure 4. Relationship of Aquifers

The Roubidoux formation consists of sandstone, dolomitic sandstone, and cherty dolomite. In central Missouri, the formation consists of sandstone horizons between bedded dolomite and chert. The sandstone is composed of fine to medium grained quartz sand which is characteristically sub-rounded and frosted. The sandstone is, in many places, characterized by well preserved ripple marks, mud-cracks, and cross bedding. The thickness of the Roubidoux ranges from 100 to 250 feet. The Roubidoux produces approximately 20 gallons per minute (gpm), which is enough for ordinary household and small farm use.

The Gasconade dolomite is a light brown to gray, cherty dolomite that averages 300 feet in thickness. The upper 50 to 75 feet is dense crystalline dolomite with very little chert . This dense rock forms a good aquitard. The next 100 to 150 feet consists of fractured chert and dolomite. This zone produces 25 gpm and is an adequate aquifer for small farms and industries when large yields are not required. The City of Rolla utilizes the Gasconade dolomite for part of its municipal water supply.

The Gunter Member, which is the 25 foot thick basal member of the Gasconade Dolomite, is composed of sandstone and sandy dolomite. It is the lower most Ordovician unit in Missouri. The depth to the Gunter Member is about 575 feet in depth at Rolla. This unit produces between 50 and 100 gpm throughout the area.

The Roubidoux formation is the closest aquifer to the Jefferson City Formation in which the landfill is located. The water producing zone lies approximately 165 feet below the bottom of the landfill. Because the Roubidoux Formation is the closest aquifer to the landfill, it has the highest potential for groundwater contamination.

Groundwater Flow

Groundwater, like surface water, flows in a down gradient direction. This down gradient direction of groundwater flow was determined from Water Well Records obtained from the Missouri Geological Survey. This was done to determine the area in which to look for possible groundwater contamination. In general, groundwater flows from wells with a higher static water level than those with a lower static water level.

As one can see from figure 5 the groundwater in Phelps County flows in a southwest direction. This map was created by using static water levels taken from Water Well Records at the Missouri Geological Survey. Once the static water level was obtained each point was given a unique x-y coordinate, with the landfill located at point (12,12), in order to create the 3-D surface map. It is

not only important to know which direction the groundwater is flowing, but also to know at what rate it is flowing. The exact rate at which the groundwater flows in this area was not determined but because of the well developed karst topography it can be assumed to have a high rate of infiltration and flow.

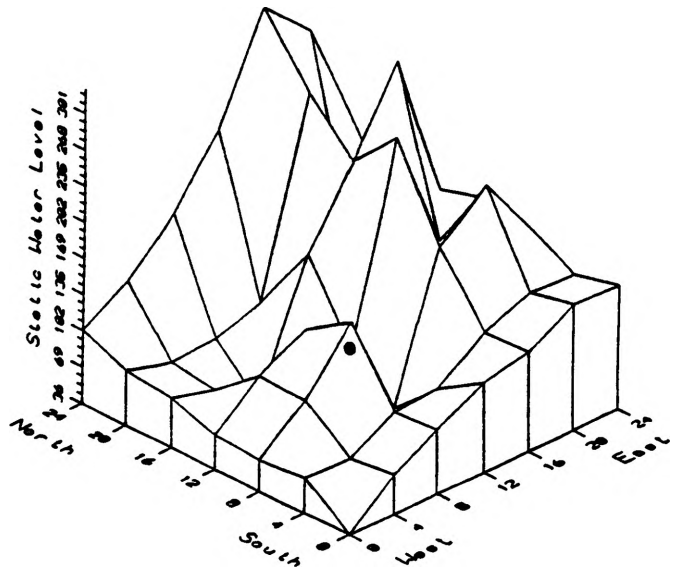

Figure 5. Southwest Direction of Groundwater Flow in Phelps County

Sample Collection and Treatment

Water samples were collected from residential housing and springs within the study area. They will be referred to by either the section number or by the distance and direction from the landfill.

At each site a 1 liter sample was collected directly from an indoor tap in a new sample bottle that had been rinsed in the lab with nitric acid and distilled water. Before a sample was taken the water was run for a period of 5 to 10 minutes and the sample bottle was washed 3 to 5 times. This was done so that the system could be purged of any solid materials that may have precipitated out of solution and settled in the pipes and to avoid metals, for example copper, which might have gone into solution during prolonged contact time with the pipe system.

Each sample was then tested for pH in the field immediately after collection and in the laboratory at the end of the day. After the pH had been tested in the laboratory, the samples were acidified with concentrated nitric acid (10 ml / L) to preserve the sample for storage.

Chemical Analysis of the Samples

The samples were analyzed in the Geochemistry Laboratory at the University of Missouri-Rolla. The equipment used for the analysis is a specific ion electrode for the pH and chloride concentration and a Perkin Elmer (Model 2100) Atomic Absorption Spectrophotometer for calcium, magnesium, sodium, potassium, and iron. See figure 6 for tabulated chemical analysis data.

Section	pH	Calcium	Magnesium	Sodium	Potassium	Total Iron	Chloride
1		70.00	41.00	3.45	1.65	0.01	4.50
3	8.05	64.00	48.50	4.95	2.00	0.10	8.00
4	7.90	71.00	50.00	3.60	2.40	0.64	5.50
5	8.00	50.00	31.00	4.30	0.82	0.01	12.50
7	7.70	55.00	37.00	4.50	1.20	0.06	18.00
10	7.85	51.75	33.95	3.40	1.25	0.65	5.75
14	7.15	85.50	49.50	11.38	1.86	0.71	15.00
15	7.80	45.00	39.50	2.85	1.81	3.10	5.50
16	7.80	54.00	31.00	11.30	1.39	0.08	16.00
21	7.40	63.00	49.50	12.65	0.98	0.45	16.50
22		59.00	36.00	4.55	1.48	0.03	5.00
23	7.65	73.00	50.40	6.30	2.05	2.31	9.20
24	7.27	137.67	89.00	7.83	3.00	3.22	9.67
29		47.00	27.00	2.57	1.03	0.03	4.50
31	8.20	40.00	25.00	2.00	0.85	0.90	3.00
36	7.70	72.50	44.00	7.78	2.00	1.05	11.25
Average	7.68	63.52	41.74	5.41	1.54	0.75	8.55
Standard Deviation	0.33	21.32	13.97	3.33	0.59	1.02	5.07

Figure 6. Tabulated Chemical Analysis of Groundwater Samples.

Specific ion electrodes are used to measure the concentration of a selected ion in solution. The concentration is measured by inserting an indicator electrode and a reference electrode into a test solution, creating a galvanic cell. The voltage of the cell, which varies with the concentration of the ions to which the indicator electrode is sensitive, is measured and compared to a calibration plot in which the measured potential is plotted as a function of the concentration in known standards of the specific ion.

Atomic Absorption (usually referred to as AA) is an analytical method based on the absorption of ultraviolet or visible light by gaseous atoms. The sample is converted into atomic vapor by spraying the solution into a flame. A hollow-cathode lamp containing the element to be determineed is used as the light source. The atoms of this element in the flame absorb at precisely the wavelength emitted by the light source. The wavelength spread is extremely narrow, both for the emission line of the light source and the absorption line of the same element in the flame. For this reason, interference from the spectral lines of other elements is almost zero.

Results and Discussion

The data from the collected samples were statistically analyzed and compared to water quality data obtained from the Missouri Geological Survey. The sample sets were compared and tested for homogeneity by a simple f-test. The results of the f-test indicate that there is no significant differences in water quality since 1985.

In order to have the most information available to study the trends in ionic concentration near the landfill the two data sets were combined and the average concentration for each ion was determined for each section. Cross-sectional graphs were created using the average concentration for each section as described. A diagram of T37N R8W sections used to create the graphs can be seen in figure 7 below.

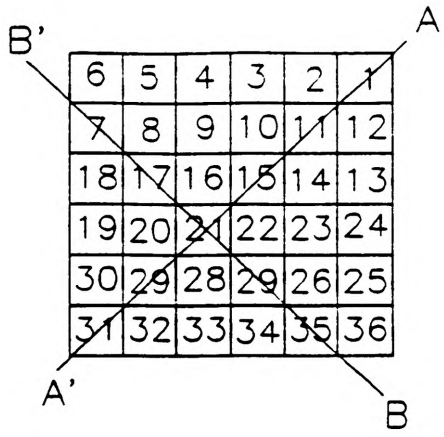

Figure 7. Diagram of T37N R8W sections used to create graphs.

The landfill is located in section 21 and is point 0 on the graph. For the graph in the northeast-southwest direction data was taken along the line from A to A'. For the graph in the northwest-southeast direction data was taken along the line from B to B'. The negative and positive ends were chosen such that the negative end is the area behind the landfill and the positive end is the area in front of the landfill in terms of the flow direction. The graphs of ionic concentration vs. distance can be seen in figure 8.

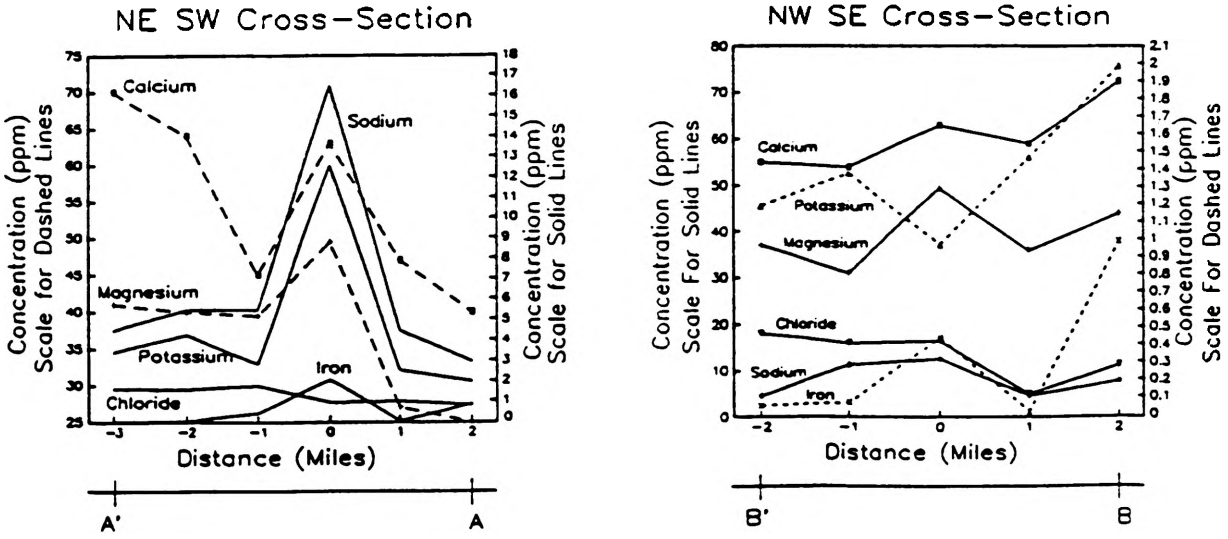

Figure 8. Graphs of Concentration vs. Distance.

As you can see in the graphs of concentration vs. distance the concentration of all the ions, except chloride, show a high concentration over the landfill in the northeast southwest direction. In the northwest southwest direction sodium and magnesium show a peak concentration: calcium, potassium, and iron show an intermediate and increasing concentration; and chloride shows and intermediate and decreasing concentration. It is interesting to see the concentration peak in the northeast southwest direction, however the ionic concentrations are well within recommended concentration limits set by the U.S. Environmental Protection Agency.

Summary and Conclusions

The McDowell Sanitary Landfill is located in Phelps County, Missouri off of Missouri State Highway CC. The topography in the area is controlled by the stratigraphy and is composed of very irregular surface and subsurface drainage patterns that are caused by extensive karst development.

Landfills are surface or near surface solid waste disposal facilities above the groundwater table. The buried refuse in sanitary landfills is subject to leaching by percolating water derived from precipitation and surface runoff. The thickness, lithology, and structure of the material beneath a landfill, and the design of the landfill itself, influence the time of waste transport and degree of modification before leachate reaches the water table.

There are two major aquifers in Phelps County that could be contamination by a leaking landfill. These are the Roubidoux Sandstone and the Gunter Member of the Gasconade Dolomite. The Roubidoux Sandstone is the shallowest aquifer and thus is the one that has the highest probability of being contaminated.

If landfills are situated in appropriate hydrogeologic settings groundwater contamination can be avoided. This study has concluded that the shallow groundwater, within a 4 mile radius of the McDowell Landfill, is not contaminated. This investigation could be expanded by analyzing for certain trace elements (e.g. heavy metals and mercury), other anions (e.g. nitrate, phosphate, and ammonium), and dissolved organic compounds.

Acknowledgments

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