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# GROUNDWATER CONTAMINATION BY SEPTIC TANK EFFLUENTS

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I am pleased to be here. Good morning everyone. I have some good news and some bad news about septic tanks. The good news is that they do not always pollute or contaminate the groundwater in excess of the standards. When they do, the contamination levels are moderate compared to what we typically see in dairies or other areas of fertilization. The bad news is that there is a lot of contamination and a lot of wells that have been contaminated by on-site systems.

Let's talk about sewage management in the state in general. Figure 1 shows information that I got from the Census Bureau. Most of the people in New Mexico are on public sewers, as you can see by the blue piece of the pie. Septic tanks, cesspools, and outside systems account for about one-third. About two to three percent of the people in the state use privies or other systems. There is some variability around the state. In Bernalillo County, obviously most of the people are on a public sewer. In Catron County, most of the people are on septic tanks. In McKinley County, we have Gallup as a large hookup to public sewers and septic tanks. About a third of the population in Gallup is on privies. That is related to the fact that about a quarter to a third of the population does not have indoor plumbing in McKinley County. New Mexico has a high level of poverty, and that is reflected in the sewage area.

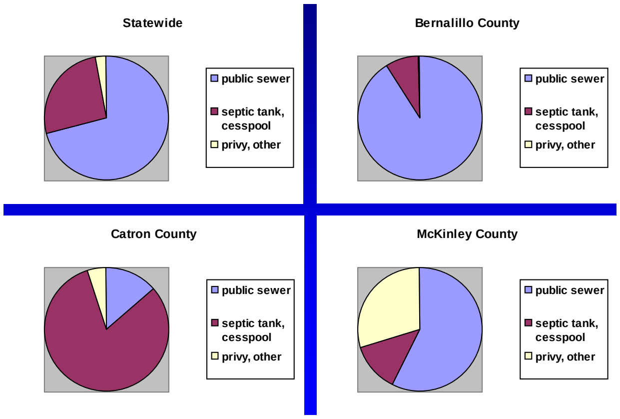


Figure 1. Sewage management in New Mexico

In New Mexico, we are approaching a quarter million on-site systems. We permit about 7,000 new systems a year. That is an increase in the past four years. We discharge about 80 million gallons per day of wastewater to the subsurface. Most of that percolates into the groundwater. Some of it is lost to evaporation. In a few areas it does not look like it gets down to the groundwater at all. What is problematic for us is that many of the areas that were developed with on-site septic systems also utilize private domestic wells.

Septic tanks are perfectly suitable as a means of on-site waste disposal if you have adequate lot size, proper soil, and if you have setbacks and clearances. John Hernandez talked about the language and statutes about reasonable degradation from beneficial use of water. The Water Quality Act and the Environment Department's regulating of on-site septics with the Environmental Improvement Act share the same principle. If you have good site conditions, septic tanks are suitable. Like I've said, most septics degrade groundwater a little bit but not in excess of standards. However, as early as 1959 the NM State Board of Health noted that septic tanks were never intended for use in closely built-up areas: "The development of fringe areas and subdivisions that do not have access to municipal water and sewage facilities is creating a continuously growing problem in proper protection of the public health in these areas. . . . Septic tanks and leaching systems were never intended for use in closely built-up areas." They were observing problems as far back as 1959. The statement written back then could just as easily have been written today about Corrales or some areas in northern New Mexico or Lake Arthur or Carlsbad; it's an ongoing problem.

Some of the regulatory problems we see with on-site wastewater systems are cesspools that have been categorically illegal since 1973, failed systems or illegal discharges that discharge on to the surface, and ground and surface water quality degradation, which can lead to the pollution of drinking water. This can not only make you sick, but stain your laundry and interfere with businesses and so on. There are public health interferences as well as public welfare and property right interferences and aesthetic issues with the water.

How many cesspools do we have in New Mexico? Cesspools have been illegal since 1973, and there is no grandfather permission available. Figure 2 is a photo of one that was being installed two years ago in Carlsbad. There were 55-gallon drums welded end-to-end; it was going to be just that with no leach field. There must be something on the Internet about putting in a cesspool with 55-gallon drums because we see these all over the place. We have done community surveys in three areas of the state assessing how many cesspools there are in these areas. San Patricio down by Ruidoso had 6 percent. Cordova, an old land grant community up by Espanola, had 96 percent. There was only one septic tank in that community. Willard had 40 percent. Figure 3 is a picture of a cesspool at a methamphetamine lab that produced a large number of bizarre chemicals we normally never see. We know cesspools are still out there, and we are working with home owners to take them offline.

Figure 2. Cesspool under construction in Carlsbad

Figure 3. Cesspool at a methamphetamine lab

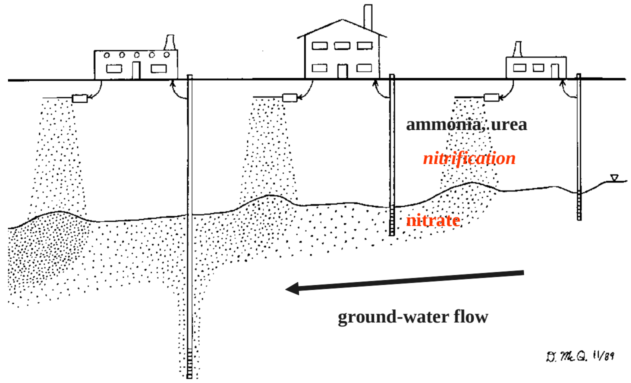


Figure 4. Drinking your neighbor's sewage

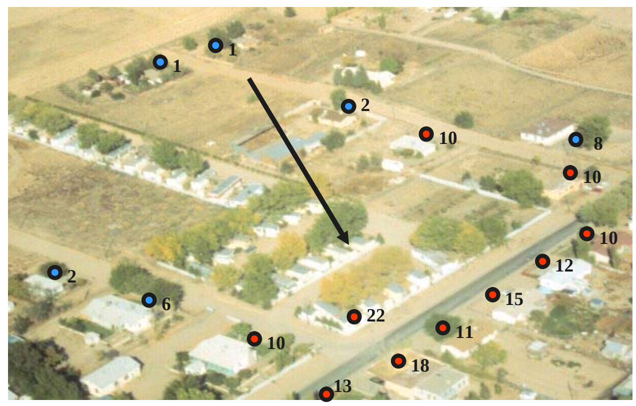


Figure 5. Barcelona $NO_3$-N (mg/L)

Now let's talk about groundwater contamination from on-site septic systems. The mineral pickup that occurs when you run water through a house includes chloride, nitrogen, calcium, sodium, and so on. Much of this is discharged down to the groundwater. If you have conditions where you don't get much nitrification of ammonia, the BOD, the biochemical oxygen demand, or your organic matter in wastewater can be biodegraded by the bacteria, and you generate respiration byproducts if you have anaerobic respiration. I will talk a little bit about that.

Organic chemicals can include pharmaceuticals, but we have not detected pharmaceuticals in groundwater in New Mexico. That is good, but we have found them in surface water. Also, dichlorobenzene is another household product. Those yellow or pink and white crystalline blocks for your toilet bowl that you can buy at the supermarket are dichlorobenzene. You can get them in packages as well.

Figure 4 is a diagram that shows what we see in a lot of areas in the state. The groundwater is flowing from right to left and it picks up minerals. As it cycles through wells and septic systems, the concentrations build up. There is very little nitrate in the raw sewage. It consists of mostly urea or ammonia, and if you have oxygen present in the soil, nitrification occurs from bacteria, and you end up with nitrate in the groundwater. This is exactly what we see in the Barcelona area (Fig. 5), which is on the west side of Albuquerque, as the groundwater flowed through this subdivision. The blue wells indicate nitrate levels less than ten. If red, they are greater than ten. As the water flowed through, the nitrogen built to dangerous levels. These are half-acre lots. They have wells in the front and septic systems in the back. This could also be Espanola, Carlsbad, and some areas of Santa Fe.

Figure 6 shows the relation between nitrate and chloride, and we have seen this in sewage. This is in the Barcelona area. The chloride was not above the standard of 250, but it was elevated. Chloride is a useful diagnostic tool that we use in fingerprinting nitrate sources (Fig. 7). If you look at the chloride from septic tanks (the red dots), the septic tanks generally produce moderate nitrate and moderate chloride levels, relative to what we see from most of the dairies. We have natural geologic sources, which I have indicated to be evapotranspiration. If you look at the ratio of nitrate to chloride concentrations in rainwater, you come up with the blue curve (Fig. 7), and this matches some extremely high nitrate levels that we have in groundwater with really low chloride. You can also eliminate some of the other major ions in these nitrate plumes, chloride, sodium, and draw stiff diagrams of this (Fig. 8). These are two septic tank cases. Again the contamination levels are not as high as you see in dairies; it happens mostly with fertilizer cases. These two cases we contribute to be from natural evapotranspiration.

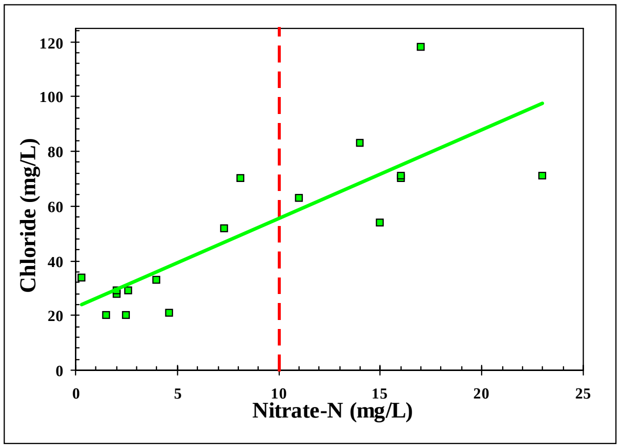


Figure 6. Barcelona nitrate and chloride

We are doing more work in fingerprinting sources of nitrate contamination. We use stable isotopes Delta and $^{15}N$. It is interesting that septic tanks in the primary and secondary sewage have similar fingerprints (Fig. 9). Once you go to a tertiary sewage process—and this is groundwater contaminated by nitrate—the bacteria take a second bit out of the $^{15}N$ or out of the $^{14}N$. They preferentially concentrate $^{15}N$ in the waste, because they preferentially utilize $^{14}N$ for cell growth. Fertilizer explosives are very light because they are made of atmospheric nitrogen, which we define as zero, our international standard. If anybody is interested, a paper is under review that goes into more detail on general groundwater.

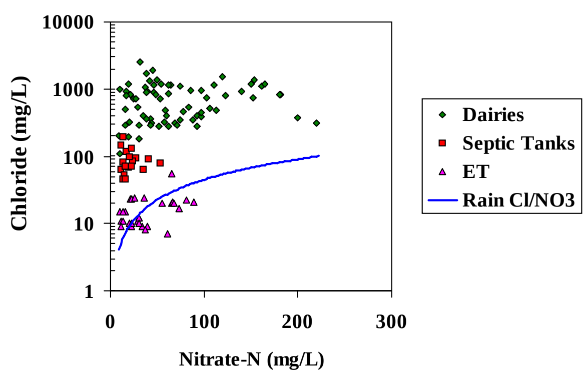


Figure 7. Nitrate source fingerprinting

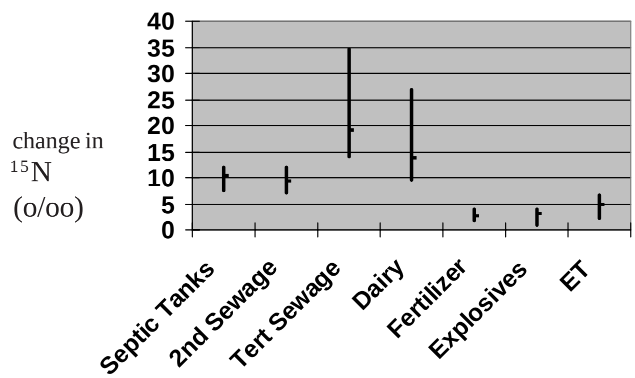


Figure 9. Nitrogen isotopes in source area groundwater

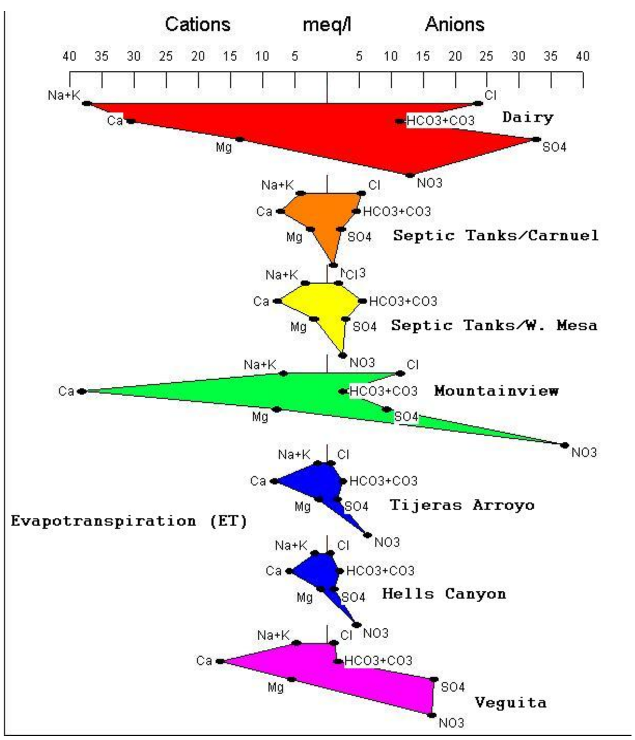


Figure 8. Nitrate source fingerprinting

We have also looked at the isotopes of hydrogen and oxygen (Fig. 10). We have found that if the water has been evaporated in a pond (see red triangles), it becomes heavier relative to meteoric water. The plumes you see from septic tanks post-collapsed the meteoric water line because there is limited potential for evapotranspiration in a leach field. It is being discharged to the subsurface.

Now let's talk about anoxic conditions. This is where the dissolved oxygen (DO) is very low or not detectable, typically less than one or less than point five. It can be caused by natural or organic deposits that you see in the Rio Grande valley, human materials, oxidation and minerals, oxidation of pyrite, for example, the mining guys know that, or biodegradation of organic matter from sewage or petroleum, any source of organic carbon. What it means for the liquid waste program is that in the anoxic areas we have decades of septic tanks and cesspools that sometimes are on really teeny, tiny lots. They have been discharging, and there is no nitrate in the groundwater. There hasn't been for decades. The ammonia and nitrate in the sewage does not nitrify. We do not find ammonia and TKN typically at detectable or certainly not in high levels in these groundwaters. We think the ammonia may be lost by cation exchange or perhaps by volatilization. If you introduce nitrate into these systems, it should denitrify, which is a process that wastewater engineers use for tertiary treatment. As you introduce organic matter, which the engineers refer to as BOD and geochemists think of in terms of organic carbon, this is a food, a carbon energy source for the bacteria. If DO is very low or not present, then the bacteria will preferentially respirate nitrate, manganese oxides, and iron oxides in soil if they are present and they usually are, or sulfate, and eventually carbon for respiration. The byproducts of this anaerobic respiration (ARBs) include soluble manganese dissolved in groundwater and hydrogen sulfite, which is the reduction product of sulfate. These cause severe aesthetic problems, and manganese has been identified as a neurotoxin.

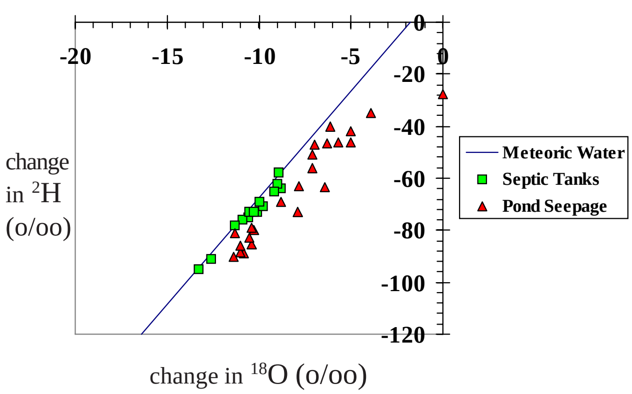


Figure 10. Evaporative fractionation

Figure 11 is the preferential sequence of anaerobic respiration. The oxygen first is smothered in bacteria, because they get more energy out of this. They use nitrate, manganese and iron oxide, sulfate, and then actually reduce carbon in the next sequence.

Thinking in a new paradigm, regulatory programs not just in New Mexico, but also in California, New York, Germany, and Israel have historically focused on nitrogen loading in nitrate. This is appropriate if nitrogen is going to be a threat, if you have nitrification

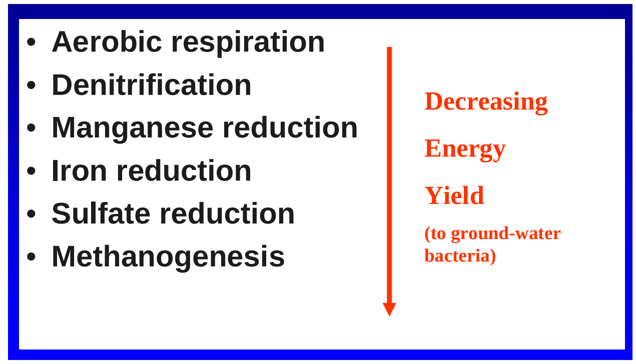


Figure 11. Respiration sequence

of ammonia, but it does not protect the groundwater from the anaerobic respiration byproducts, the manganese and iron and hydrogen sulfite. We need to protect our groundwater from this. Additionally, nitrogen reducing wastewater treatment may not be appropriate if you have widespread anoxic conditions. The liquid waste regulations now recognize that. It is a very controversial issue, and I would be more than happy to discuss that with any of you.

Let's look at some of the data from New Mexico. I borrowed Figure 12 from the USGS. This shows dissolved oxygen less than 0.5. There is an area that is shaded in the Rio Grande Valley where I think you can make a strong argument that this is largely a natural condition, where the human materials have moved in and caused depletion of oxygen and the depletion of water was introduced. If you look at dissolved oxygen and nitrate concentration, then you get a pretty good match with the areas that have high densities of septic systems and cesspools (Fig. 13). Bernalillo is right up in here. Corrales is here in our valley. We think this is good evidence that the on-site systems are contributing to the contamination of anaerobic degradation byproducts.

Look at manganese as we go down in sequence. Figure 14 shows wastewater loading in the South Valley of Albuquerque, a high density area with small lots. This also corresponds to the high levels of manganese in groundwater (Fig. 15). We have looked at iron as well. Figure 16 is Corrales based on some work we did last year. The inner valley has no nitrate to speak of. It is usually not detectable. We find lots of high iron levels. Similar, to the west we seldom see any iron but we detect nitrate greater than two. There is a pretty good redox boundary near Corrales.

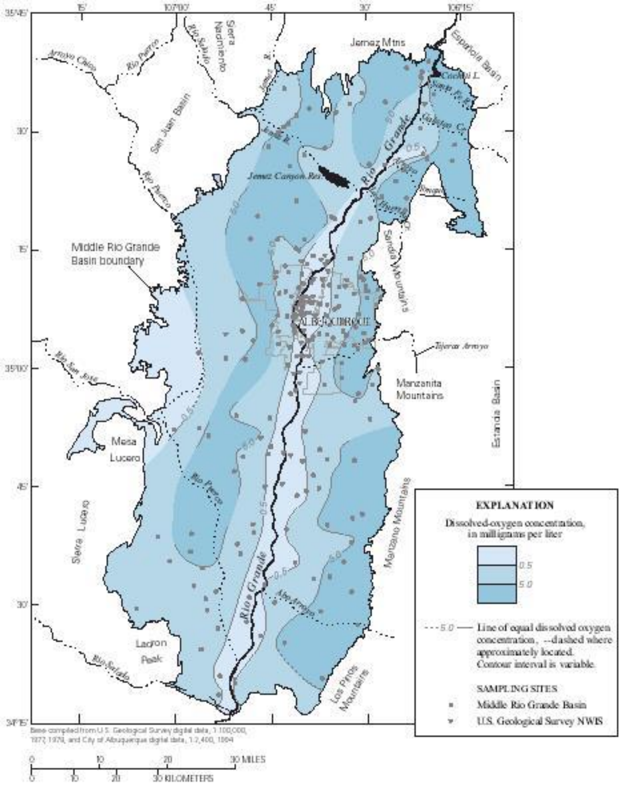


Figure. 12. Anoxic groundwater - Middle Rio Grande Valley

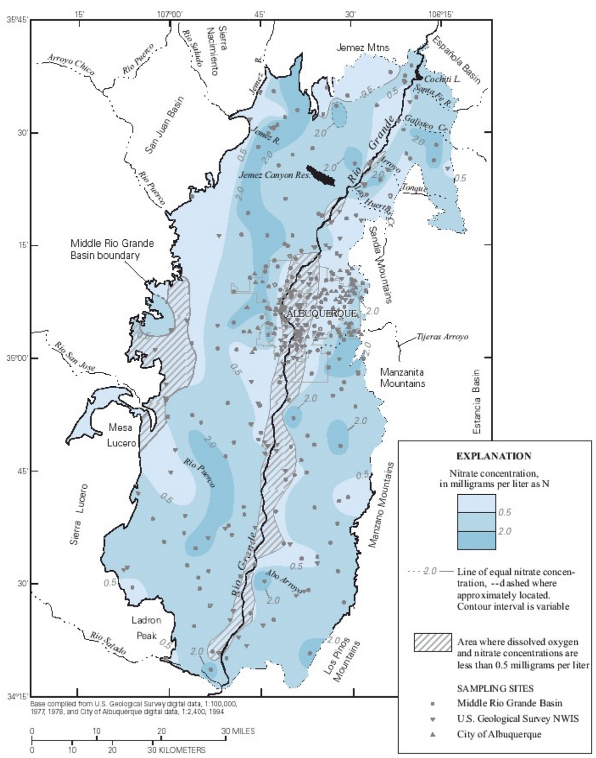


**Figure 41.** Nitrate concentration for ground water of the Middle Rio Grande Basin, New Mexico.

Figure 13. Anoxic and $NO_3$ depleted groundwater - Middle Rio Grande Valley

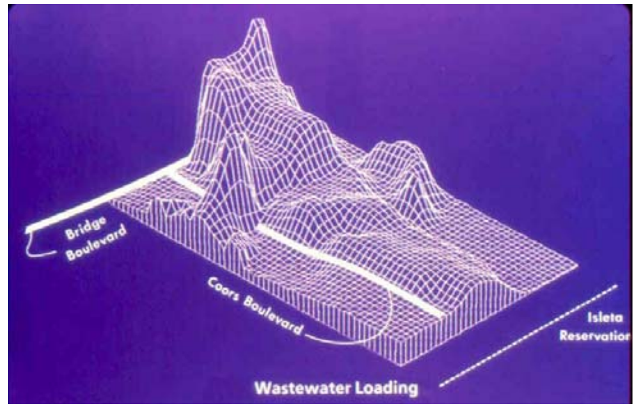


Figure 14. South Valley wastewater loading

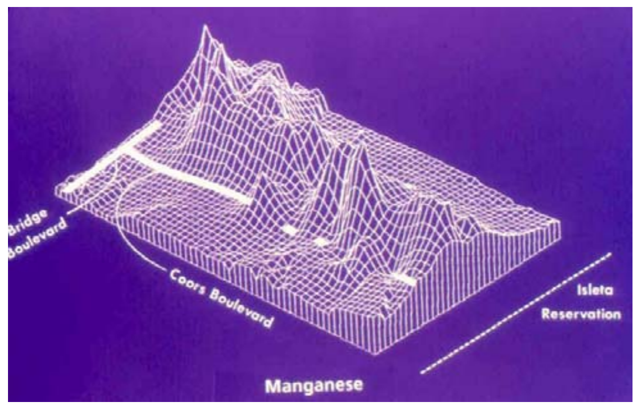


Figure 15. South Valley groundwater manganese

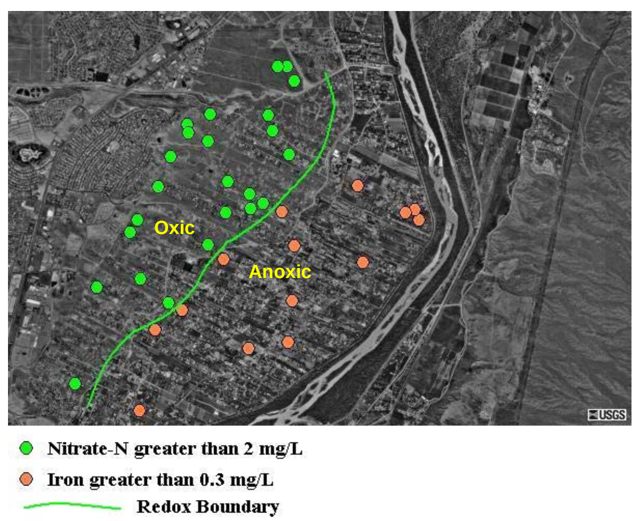


Figure 16. Corrales groundwater chemistry

The Water Quality Control Commission (WQCC) in 1989 identified, based on information we have given them, septic systems as being the largest source of groundwater contamination in the state. This is why: if you look at all the wells that have been contaminated by on-site systems, count them up, and compare them to all the wells contaminated by dairies, mines, landfills, and methamphetamine labs, the on-site systems contaminate more wells than all of the other sources combined (Fig. 17). This is based on nitrates above ten or iron and manganese in excess of the standards set by the WQCC in the public water supplies.

Figure 18 shows the distribution of groundwater contamination statewide. Again, a lot of contamination has occurred. The public drinking water systems that Kim talked about, all those 1,300, have had source water assessments. We go out and look at what potential sources are within a 1,000 foot radius. Figure 19 is Gabaldon over in San Miguel County. This well has high nitrate levels, above ten, and it is a public water supply. You can look at all the septic systems that are within 1,000 feet as well. Septic systems have been identified, based on these source water assessments, as the biggest potential threat to public water supply wells in the state (Fig. 20). Then we have grazing and farming. If you included them as a category of agriculture, then they collectively make up another third. Then we have industrial and miscellaneous uses as well. This is consistent with the data from contaminated public supply wells.

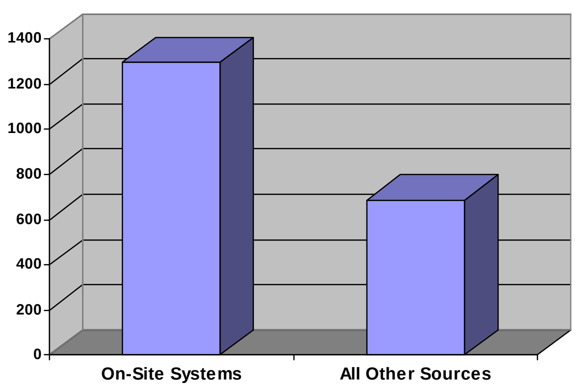


Figure 17. Contaminated wells in New Mexico

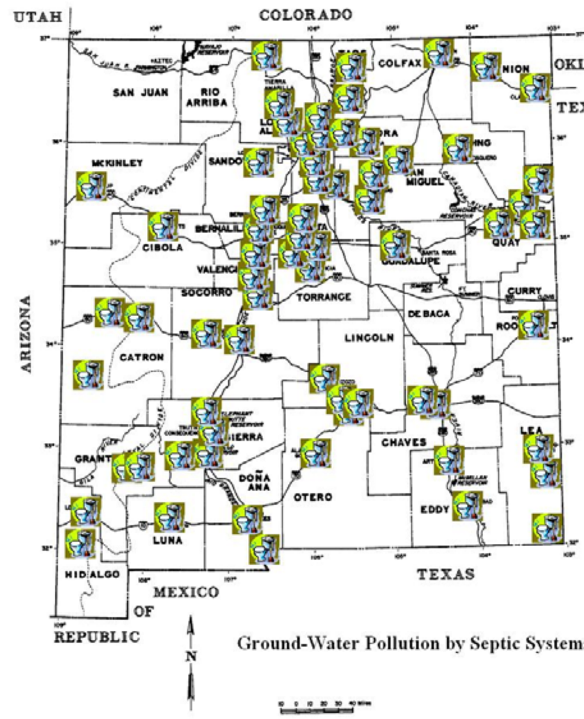


Figure 18. Groundwater contamination from onsite septic systems

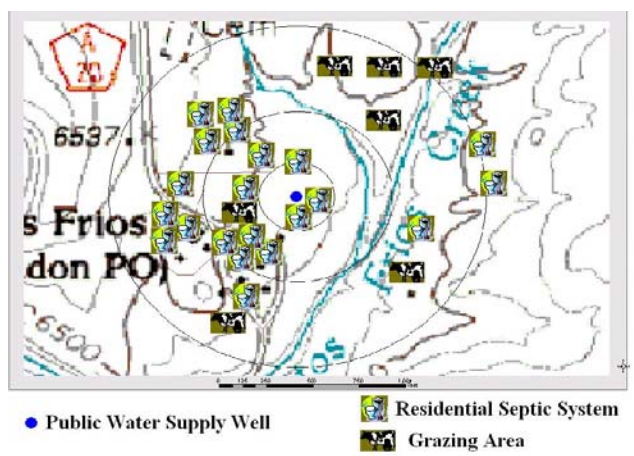


Figure 19. Gabaldon source water assessment

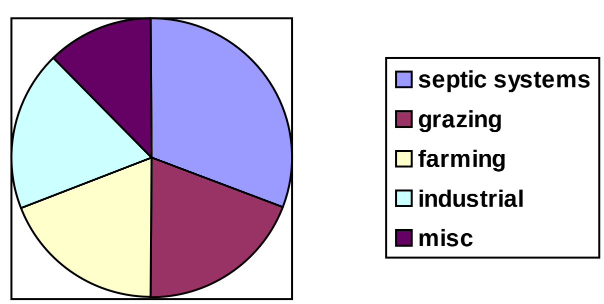


Figure 20. Risk summary for public wells

The vulnerability factors for groundwater contamination include wastewater flow, vadose-zone conditions (redox, percent saturation, hydraulic conductivity), depth to groundwater, groundwater conditions (redox, hydraulic conductivity, gradient), lot size, and nearest down-gradient supply well. I want to emphasize depth to groundwater and lot size as being important. Figure 21 is available on our geographic information system via our website. These are maps that Lee Wilson prepared for the department about 20 years ago. We have digitized them and put them up for viewing. We would like to update these maps and work with more data. Figure 21 is Sandoval County, which includes Rio Rancho and Corrales.

Figure 22 is a comparison of the nitrogen loading in pounds of nitrogen per acre per year versus the nitrate increase that we have seen. Read that to mean lot size for non-point sources. This curve is what you get when you run all of the models that have been used by the USGS and by Bernalillo County. This curve shows the actual data for the New Mexico field site. We have areas where we have looked at what nitrate has been added to groundwater and the effect of lot size from all of those septic systems. In general, the model is predicting a more severe impact than we have seen in groundwater, with the exception of sites with fractured bedrock where the average lot size is more than three acres. The purple line is the allowable lot size under state regulations. You have two sites with nitrate contamination in excess of the drinking water standard of 10. That has occurred on lots larger than the minimum required by state law. This is a very important finding.

We have some 400 miles of streams in New Mexico that have been adversely impacted by septic tank effluent, typically by elevated nutrients (Fig. 23). This is the Rio Ruidoso. It shows eutrophic algae bloom. Septic tanks are contributing to that condition. We have streams that have contamination from septic tanks, and septic tanks in the area.

We have seen several health hazards from the contaminants we are talking about. We have had blue babies in New Mexico. Manganese is a neurotoxin. We have also traced specific outbreaks of disease to wells contaminated by sewage. Those of you who enjoy spinach salad probably know all about E. coli. We have had the same issue with well water.

Alternatives exist to conventional septic systems including advanced wastewater treatment units, which are like mini sewage treatment plants. They can perform

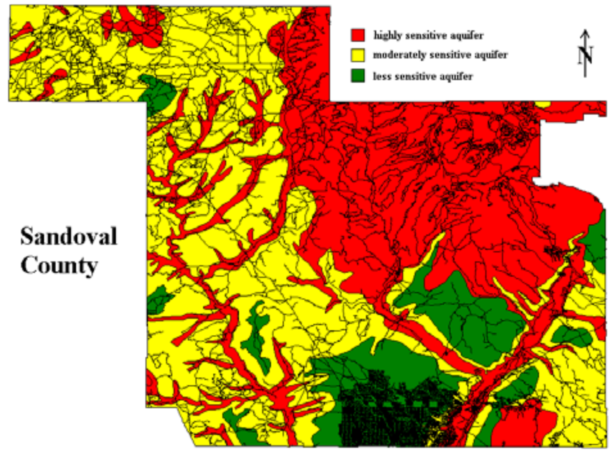


Figure 21. Aquifer vulnerability

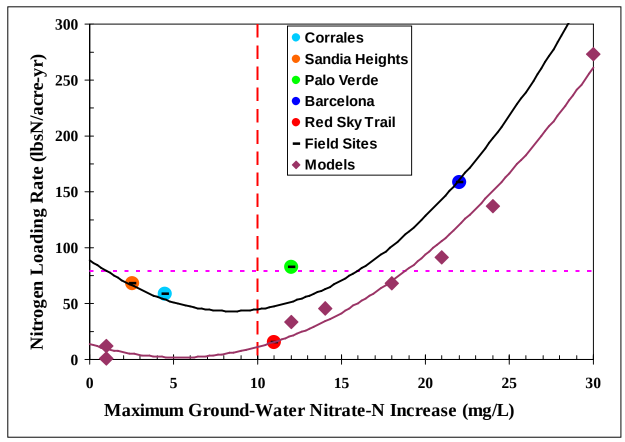


Figure 22. Lot size (nitrogen mass loading) and ground-water nitrate increase

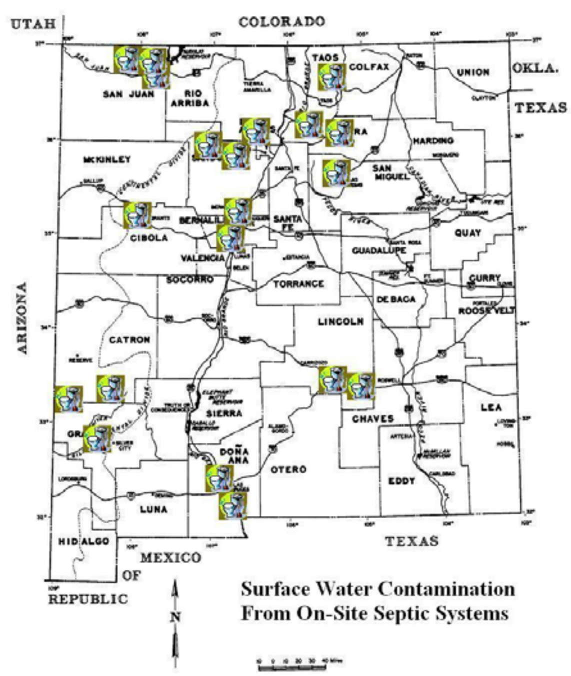


Figure 23. Contamination of gaining streams

secondary and tertiary treatment. There are non-discharging systems and split-flow systems, where you separate the black water from the gray water. The gray water goes to a holding tank, which is about ten percent of the flow and 90 percent of the nitrogen and organic matter. Centralized management of septic tanks is another method. Clusters, where you take four, ten, or a number of houses, and hook them up to one advanced treatment system is another option. There are economic advantages to that option for the homeowners; it is not as expensive as everyone having their own advanced treatment system. Also, there is the sewer, or big pipe, solution.

Question: Septic tank legislation was talked about earlier. Do you know more about that?

Dennis: Cindy Padilla mentioned that yesterday. Bernalillo County has a program that is funded by a portion of their liquid waste permit fees. Fees go into a fund where they can use that money to hook up indigent households to a city sewer or to install a properly permitted septic tank. We are looking at legislation similar to that on a statewide basis. We have a lot of poor people in New Mexico. Some of these people have cesspools. If we could just use a portion of our fee money and some seed money from the legislature, we could greatly improve things.

Question: How does one determine which areas are sensitive and which are not?

Dennis: The criteria that Lee Wilson used for those maps was the basis of depth to groundwater and to some extent TDS. In Sandoval County where the TDS is usually pretty good, it was strictly depth to groundwater. The red areas were less than 100 feet to groundwater. The yellow areas were 100 to 300 feet to groundwater, and the green areas were greater than 300 feet to groundwater. If you look at Lee's maps in the south part of the state, then TDS became part of the equation. The vulnerability got downgraded as the TDS went up above, I think, 3,000 or 5,000.

Question: That map is from 1979, and it is fabulous work done before GIS. We need to update that. It needs to be a major priority.

Dennis: We do need to update the map. I am glad you mentioned GIS because of the governor's designation of 2007 to be the Year of Water. We have been directed to overhaul our environmental GIS. We have a GIS system online right now, and we have been directed to add a lot more data. One of the things that needs to be done is to update that map. We have a lot more information now, more wells, and so on.