Chapter
1

# Hydrogeology, Aquifers, and Geology

Two aspects of water are key to an understanding of contamination at nuclear weapons plants and radioactive waste burial areas: Water moves underground all the time (although sometimes this motion can be very slow), water is among the most essential resources affecting municipal, agricultural, and economic activity.

Groundwater refers to subsurface water – water that has percolated down into the soil. In the United States, groundwater is key to our water supply systems. It accounts for approximately 42% of the public and domestic water supplies (surface water and water reuse account for the remainder); irrigation of crops is the largest use of this groundwater.[1]

The rate at which radionuclides and toxic chemicals move underground is absolutely dependent upon the rate at which the water moves. If water moves, radionuclides move. If water is relatively stationery, radionuclides stay in that spot. With the exception of radionuclides that assume a gaseous form, such as iodine-129, radionuclides move at a rate proportional to the speed of underground water. Some radioactive materials, such as tritium, move at the same speed as water.

Historically, groundwater has been neglected as a factor in the siting and design of nuclear weapons plants and radioactive waste disposal areas because it is neither seen nor is it vividly present. The only important water consideration to nuclear weapons plant designers was its plentitude in nearby surface and underground sources.

Furthermore, most of the plants were built during World War II's Manhattan Project. At that time policy makers were so focused on the urgent need to quickly and secretly design the atomic bomb, environmental considerations were a low priority.

Finally, back in the 1940's and 50's, adequate mapping of underground water resources simply didn't exist and the science of hydrology (the study of water, its properties, and how it behaves) was in its infancy. Environmental siting laws were virtually nonexistent. As a result of all these factors, the plants were sited in particularly inappropriate locations with regard to the potential for pollution of water and the offsite migration of contaminants.

## Hydrogeology

In order to understand the crucial role groundwater plays to society and the importance of removing contamination at each site, we must first understand the role of hydrogeology.

Hydrogeology is the branch of geology that deals with the occurrence, distribution, and effect of groundwater. Contrary to popular belief, groundwater is not typically found underground in the form of a body of water, similar to rivers or lakes. Rather the water is contained in the pores, cavities, and voids interspersed among rocks, gravel, sand, and soil in the earth's subsurface. When useful extractable quantities of water in these geologic formations are found, they are known as aquifers; aquifer means, "water bearer."

## Hydrologic Cycle

Through the hydrologic cycle, groundwater is circulated and used in many different areas. The hydrologic cycle is the continuous circulation of water near the earth's surface through precipitation, evaporation, transpiration, infiltration, groundwater flow, and runoff. Whether it is being evaporated from the world's oceans, lakes and ponds, falling down from clouds as rain or snow, running down rivers, brooks, and streams back towards the oceans, or rising from plants and trees as evapotranspiration, water moves through the elements of planet earth in this endless cycle.[2]

Some of this movement is highly visible to our senses. Whether it is ocean waves, fog rising off of lakes, river currents, rain or snow, all these forms of water are very familiar to human beings. One place where this vital cycling of water is less obvious to people is below the ground. Like more visible sources of water, this underground water is subject to gravity and consequently is also continually moving, traveling, migrating, seeking new levels. Over time (months, years, or decades) this water joins and blends with other more visible water sources, such as swamps, marshes, lakes, springs, rivers and streams; eventually groundwater is cycled back to the sea.[3]

When water reaches the surface of the earth it may run off or percolate down. In either case, the water can become contaminated by activities on or near surface of the earth. After the soil becomes saturated, the excess water will runoff. If the earth's surface is contaminated, as is the case at many nuclear weapons plants, the runoff spreads contaminants across the site and to nearby bodies of water.[4]

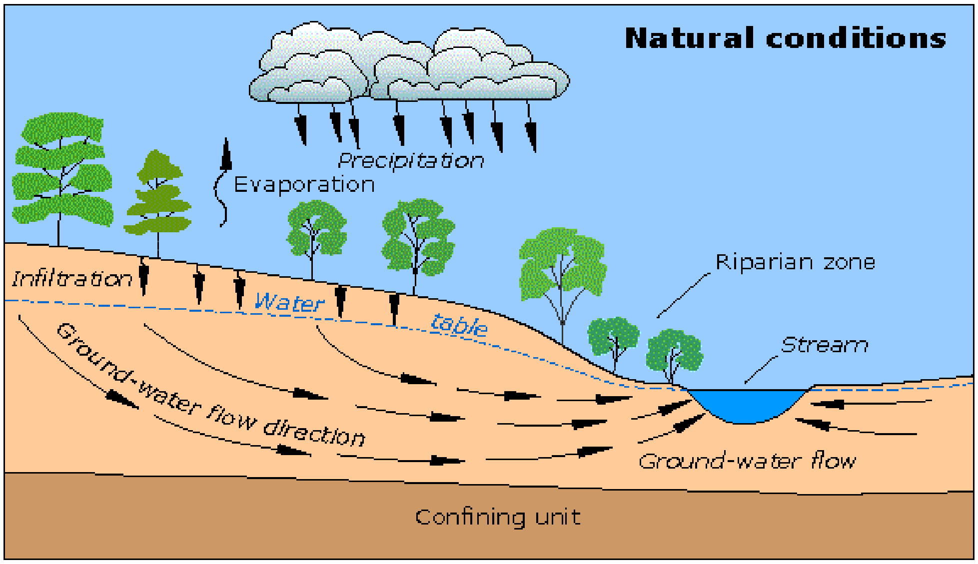

**Figure 1.** Map of the hydrologic cycle. <http://wwwga.usgs.gov/edu/earthgwdecline.html>.

## Groundwater

When the soil is not saturated, the water can percolate down into the soil; in the subsurface, water is referred to as groundwater. Groundwater may flow for miles before it discharges into springs, lakes, rivers, marshes and oceans. The water that enters the subsurface infiltrates through rock and soil. The rate of infiltration is dependent upon the permeability of the materials in the subsurface. Typically, soils of higher permeability are composed of loose, dry, and sandy soils, while soils of lower permeability are composed of compacted wet clay soils that in turn absorb water at a slower rate.

Rates of infiltration into the soil are enhanced by tunnels, cracks, fault lines, and, sometimes by the activity of man, such as the use of hydrofracturing at waste sites.[5] Hydrofracturing is a technique of waste injection. Water is forced down deep beneath the surface of the earth to create fractures or holes; then the nuclear waste is encapsulated in concrete and lowered down into the holes. This technique can create unintended horizontal fractures deep below the earth along which the waste may eventually move, when the concrete packages degrade. Hydrofracturing was used extensively at Oak Ridge.

In order to understand the complex pathways by which water moves underground, scientists have categorized the different zones through which groundwater moves. There are two main zones: unsaturated and saturated.

## Unsaturated or vadose zone

As precipitation, such as rain or snowmelt, reaches the surface it seeps into what is known as the unsaturated or vadose zone. This zone, lying immediately below the surface, is also sometimes called the "zone of aeration." Here the small spaces between soil particles are filled with a mixture of water and air resulting in an area that is less than saturated; therefore the zone is unsaturated. Water in this zone is called capillary water.

Capillary water is water that moves upward from the water table by capillary action. This water moves very slowly and in any direction. Water cannot be withdrawn for residential or commercial water supply purposes from this zone because the capillary forces hold it too tightly. The roots of trees, plants and crops, however, can tap into this water.[6] Plants, crops and trees depend upon water from this zone. In addition the unsaturated zone sustains vital, biological activity such as insects, worms, grubs and some mammals.

The depth of the unsaturated zone varies tremendously depending upon the thickness of rocks and sediments that make up the saturated zone beneath it. Many of the low-level burial sites discussed in this report are located directly in this zone. Some of these burial areas were specifically *designed to leak* into the unsaturated zone, such as the burial pits in use at Oak Ridge National Laboratory between 1951 and 1965.[7]

As water is deliberately or accidentally dumped into the ground, it continues to enter the unsaturated zone and travel through the zone and downwards towards the water table. Contaminants in the soil, even those temporarily adhering to soil and clay particles, are eventually washed downward. The time frame for this downwards movement depends upon many complex factors.

## Water table

The water table is the boundary between the unsaturated zone and the saturated zone. In this area, no fluid pressure is present. The depth of the water table can range from zero feet (at the surface) to hundreds of feet beneath the surface. The configuration of the water table varies over time and the changes are attributed to the amount of recharge to the groundwater.[8]

As a water table rises up to the surface, the soil becomes waterlogged and the only plants that survive here can tolerate having their roots permanently wet, such as reeds and sedges. These saturated areas are swamps, bogs and marches, also known as wetlands.[9] Several burial grounds at the Oak Ridge facility are located directly in the water table. This means that soluble radionuclides, such as strontium-90, in the buried waste are regularly flushed out and released to the environment.[10]

If a water table is shallow (0 to 100 feet), it is a problem for radioactive waste disposal. This has been the case at Savannah River where the leaching of contaminants from burial areas into the water table and the site's many shallow aquifers has occurred.[11]

The phrase *water table* can be confusing. It implies that the water is level or flat, similar to a table. Actually the height of the table will fluctuate depending upon the nature of the pore space in which the water sits. Water sitting in very narrow pores, such as those found in clay soils, will be lifted by capillary action, often by 10 feet or so.[12]

Another misconception about a water table is that it somehow acts as a barrier to the movement of contaminants. This is not the case. Once pollutants reach the water table, they will continue to travel in the direction of the water flow and eventually reach the aquifers, the water-bearing geologic formations in the saturated zone, or the pollutants will travel laterally underground to reach nearby streams, lakes and rivers.

## Saturated Zone

The saturated zone is located beneath the water table. The water located in this zone can be withdrawn for use. If underground formations of permeable or porous geologic mediums (rocks and other loose or unconsolidated materials) contain useful quantities of extractable water they are known as aquifers. In general, we tend to think of rocks as solid, unyielding surfaces, but many underground rocks are extremely porous. These rocks can store large amounts of water.

The water in aquifers is contained in interconnected openings filled only with water. It is the lack of air that makes the groundwater accessible to be withdrawn. The channels of the aquifer are saturated with water and the upper limit of this region is the water table.

The variation in the flow of groundwater depends on the type of rocks or other permeable material, the size of the spaces in the soil or rock, connectivity of spaces, and the configuration of the underground strata. Certain geologic media are more likely to contain aquifers than others. These include unconsolidated deposits of sand and gravel, sandstone, interbedded sandstone and carbonate rocks (such as limestone and dolostone), semiconsolidated sand, basalt and other types of volcanic rock.[13]

Sometimes people think of underground water as traveling like a river underground. Actually the water is held within tiny pores of the geologic medium, and gravity forces the water to move from one pore space to another. Other features of the rocks and geologic media that store and conduct water are cracks, fissures and fractures.

## Cracks and fissures

Cracks and fissures can cause water to travel very quickly and for long distances underground. These pathways can become subterranean streams, carrying water rapidly to nearby rivers. If these underground pathways have not been detected by geological surveys, contaminants in underground rocks can move swiftly to unexpected locations, thereby greatly complicating remediation of waste sites. This has been a repeated problem at nuclear waste sites.

Sometimes DOE policy has deliberately created fractures underground for the storage of waste. As mentioned earlier, the underlying shale beneath Oak Ridge was hydrofractured; water was forced down under pressure to create fractures and then waste, encapsulated in concrete, was buried in these fractures. This resulted in more underground fissures along which the radionuclides and other contaminants can migrate once the concrete sleeves containing the encapsulated wastes break down. Then, the contaminated materials will enter the subsurface and travel to the aquifers. Hydrofracturing was abandoned in 1985.[14]

## Aquifers

These permeable water-bearing units of rock or soil are vital sources of water for the human community. There are three broad categories of aquifers: unconfined, confined, and perched. Both the confined and unconfined layers may contain significant sources of groundwater that are accessible sources of drinking water.[15]

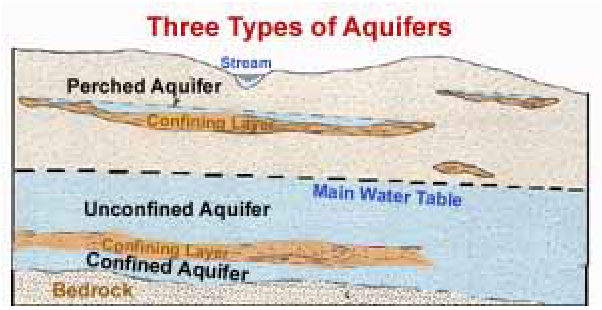

**Figure 2.** Three types of Aquifers. Driscoll, Fletcher G. (1986). *Groundwater and Wells*, 2nd ed. New Brighton, MN: US Filter/Johnson Screens.

## Unconfined aquifers

Unconfined aquifers are most susceptible to contamination from activities on the soil's surface. The pressure is atmospheric throughout unconfined aquifers. In these aquifers, the groundwater only partially fills the aquifer and geologic media does not confine the upper surface of the groundwater. Instead the upper boundary of an unconfined aquifer is the water table. At this point, the water table is free to rise and fall and typically mimics the land surface above, so the water table can have hills, valleys, or flat areas. Due to the lack of an impermeable barrier above this type of aquifer, unconfined aquifers are highly vulnerable to contamination.

## Confined aquifers

A confined aquifer is located between layers of impermeable materials that restrict the flow of water into and out of the aquifer. Pressure in this aquifer is high due to the confining layers that enable the water level in wells to rise above the typical water level of an aquifer. Confining beds are beneficial in restricting the flow of contaminants from overlying unconfined aquifers by impeding the flow of water into and out of the aquifer as a whole.

## Perched aquifer

A perched aquifer refers to groundwater that is separated from the underlying main body of ground water, or aquifer, by unsaturated rock.

## Recharging aquifers

The rate of recharge to aquifers is an important factor in determining how fast pollutants may travel offsite. Recharge to aquifers is affected by the permeability of the soils as well as by precipitation, snowmelt and rain, leaks from burial grounds, trenches, pipelines and canals, releases of wastewater and irrigation of over-saturated crops.

Rivers and streams both serve as a source of recharge for the aquifers and may receive contamination channeled to them by the site or by an aquifer. Not only are aquifers recharged by surface water, but aquifers also discharge into rivers, lakes, or oceans through vegetation, evaporation, and pumping wells. For example, contaminants traveling underground at the Hanford site have placed the Columbia River at risk. The Columbia River extends 1,210 miles. Not only are the cities of Richland, Hood River, and Portland that draw municipal water downstream from the Columbia River at risk, but also downstream aquifers can be contaminated by pollutants in the river.

Another contributor to the recharge of the aquifer is climate. Sites located in the southwestern United States are typically dry with minimal precipitation on the surface, aside from runoff from the mountains and flash flooding. Sites located in the southeastern United States are typically humid with prevalent surface waters, such as marshes and lakes. Located in South Carolina, the Savannah River Site is in an area of heavy rainfall, consequently contaminants move quickly and are currently migrating offsite underground and through surface pathways.

In contrast to the humid southeastern portion of the United States, the southwestern portion is characteristically dry. At the Nevada Test Site recharge rates are slow, however there are major contamination problems from underground testing.

The Great Miami Aquifer is recharged by the Great Miami River as well as by Paddy's Run, a stream that travels partially beneath the Fernald, Ohio plant. Contaminants were washed from the surface of the site into Paddy's Run where the contaminants were carried to the groundwater supply below.

## Sole-source aquifers

One of the most important types of aquifers, in regards to environmental contamination, is the sole-source aquifer. "A sole-source aquifer provides a minimum of 50% of the water for users in a situation where no other source of water could reasonably replace it."[16] An example of a sole-source aquifer threatened by a radioactive waste facility is the Snake River Aquifer. This aquifer is designated as a sole-source aquifer by the US Environmental Protection Agency because it is the only source of drinking water to 200,000 persons in southern Idaho. The Snake River Aquifer spans 10,000 square miles and is the second largest aquifer in the US. It is at risk from wastes disposed of improperly at Idaho National Engineering and Environmental Laboratory.

If a sole-source aquifer becomes contaminated, the impact on municipalities, farming, and agriculture can be particularly grave. Contamination of the aquifer also has a negative impact on adjacent businesses. For example, in Idaho, the trout farming business potentially could be greatly affected by the contamination of the aquifer; seventy-five percent of the commercial rainbow trout eaten in the US comes from trout farms relying on the Snake River aquifer. Once the aquifer is known to be contaminated, it would be, as a local trout farmer said, "disastrous" for the local economy.[17] The Great Miami Aquifer in Ohio is also a sole-source aquifer providing water to surrounding water companies and privately owned wells.

The contamination of any type of aquifer, not only sole-source aquifers, greatly affects surrounding communities.

### Delineating aquifers

Aquifers can prove to be quite complex, although textbook definitions make them sound very neat and discrete. For example the Hanford site has both confined and unconfined aquifers. Determining the exact boundaries of these different underground strata is extremely complex; in turn, defining the routes along which the contaminants are moving is equally complicated through the infiltration or recharge of the aquifer.

Delineating the boundaries of aquifers and defining which types of aquifers are present are key tasks in helping to remediate waste sites and to design safe, long-term solutions. Such delineation requires extensive research and field-testing. Often the understanding of the types of aquifers present is hard to ascertain because waste facilities are sitting directly on top of the areas that need to be characterized. Also the official version of these boundaries can shift over time as more detailed tests are completed. Often past assurances by DOE that a confining aquifer is the only aquifer present have needed to be revised.

### Aquifers affected by contamination

The Ogallala Aquifer is the largest single water-bearing unit in North America. It is a 100-metre-thick band of sandy material that is estimated to stretch through 174,000 square miles beneath a large number of Great Plains states. Sometimes this aquifer is also called the High Plains Aquifer. It stretches from West Texas to South Dakota and is found underneath parts of Oklahoma, New Mexico, Kansas, Colorado and Nebraska. Six states and a dozen cities depend on this enormous underground storage basin for water. A large proportion of US grain grown for export purposes, such as wheat and corn, and almost one-half of America's beef is grown using water drawn from the Ogallala Aquifer.[18] The Pantex Plant is situated directly above this aquifer. Contaminants from Pantex, such as TCE and chromium, have been measured at higher than allowable levels in the aquifer.

Other large aquifers impacted by radioactive waste disposal are the Tuscaloosa Aquifer and the Great Miami Aquifer. The Tuscaloosa Aquifer is a major aquifer for the southeastern United States. It is considered the greatest water recharge area on the southeastern seaboard. The Savannah River Plant sits on top of this aquifer putting this major groundwater resource at risk. The contamination is migrating offsite through surface and subsurface pathways.

At the Fernald Site in Ohio, Paddy's Run Creek travels underground across a portion of the site. This stream carries contaminants into the subsurface enabling the spread of contamination into the Great Miami Aquifer. In addition, the Mound Site is also located above the Great Miami Aquifer. This aquifer flows beneath the entire site and the majority of southern Ohio and is one of the nation's largest drinking water aquifers, containing almost 10 trillion gallons of water; all of the drinking water for the city of Cincinnati is withdrawn from this aquifer.[19]

### Aquifers in the desert

The Nevada Test Site is located in the southwestern portion of the United States, in the Death Valley Groundwater Basin. Although the climate is characteristically dry, the groundwater flow beneath the site is complex and involves many aquifers and confining units. Because of the multiple aquifers beneath the Nevada Test Site and a long history of underground explosions, there is a significant contamination problem at the site.

The sites and their primary aquifers that are researched in this report are listed in the table below. These 13 sites are discussed more fully in later chapters.

| SITE | STATE | Primary Aquifers found beneath the sites |
|---|---|---|
| **Fernald** | Ohio | Great Miami Aquifer |
| **Hanford** | Washington | Located in the Ringold Formation |
| **Idaho National Engineering and Environmental Laboratory** | Idaho | Snake River Plain Aquifer |
| **Los Alamos National Laboratory** | New Mexico | Located in the Tesuque Formation |
| **Lawrence Livermore National Laboratory** | California | Located in the Livermore Formation |
| **Mound Environmental Management Project** | Ohio | Great Miami Buried Valley Aquifer |
| **Nevada Test Site** | Nevada | Lower Carbonate and Upper Cenozoic Aquifer Systems |
| **Oak Ridge** | Tennessee | Knox Aquifer |
| **Paducah** | Kentucky | Regional Gravel Aquifer |
| **Pantex** | Texas | Ogallala Aquifer |
| **Portsmouth** | Ohio | Berea and Gallia Aquifers |
| **Rocky Flats** | Colorado | Denver Basin Aquifer |
| **Savannah River Site** | South Carolina | Steed Pond, Crouch Branch, and McQueen Branch Aquifers |

## Geology

If hydrology is key to understanding how water moves underground, geology is key to understanding the various routes by which contaminants can move beneath the earth's surface. Geology is the study of the planet Earth. "Geology holds the key to waste disposal to the land environment. Unfortunately, the desired degree of reliability of determination of the geologic parameters is not amenable to precise definition. Generally, it can yet be based upon seasoned judgment and experience. We dare not compromise radiological safety. Until the geologic parameters can be defined far more quantitatively than now, waste disposal to the ground must not become a widely used method of disposal."[20]

## The subsurface

The Earth is approximately 7,905 miles in diameter, and its subsurface is comprised of three main layers: the crust, the mantle, and the core. The crust is the outermost layer where groundwater is contained; it is a thin rigid layer, approximately 62 miles thick. In this report we are only concerned by processes in the upper crust; due to extreme temperatures in the deeper subsurface, groundwater is only located in this layer.[21]

It is extremely difficult to characterize the underground geology due to the complexity beneath each of the sites. For instance there may be interbedding with a highly permeable strata like sand threading through a more impermeable clay strata. Or there might be a tiny fracture in a rock where the groundwater would flow faster. In both instances the permeable strata or fracture might not be detected by core samples taken even at quite frequent intervals. At none of the sites was the geology fully characterized before construction of weapons plants began. This fact has made subsequent characterization very difficult since nuclear reactors, buildings and landfills have all obscured the geology beneath them. Processes differed at each of the sites and thereby many contaminants were released into the environment throughout the years of operation.[22] Certain contaminants at each of the sites are more prevalent and are listed in the table below. Again, each of these sites is covered in greater detail in individual chapters.

| SITE | Contaminants in the subsurface of extreme concern |
|---|---|
| **Fernald** | radium, thorium, and uranium |
| **Hanford** | carbon tetrachloride, plutonium, cesium, iodine and uranium |
| **INEEL** | TCE, tetrachloroethene, and dichloroethene, plutonium, and tritium |
| **LANL** | Plutonium and uranium |
| **LLNL** | TCE, tritium, and uranium |
| **MEMP** | tetrachloroethane, TCE, and 1,2,-trans-dichloroethane, plutonium, and tritium |
| **NTS** | Plutonium, tritium, and uranium |
| **Oak Ridge** | carbon tetrachloride, plutonium, technetium, tritium, strontium, and uranium |
| **Paducah** | technetium, trichloroethylene, and uranium |
| **Pantex** | plutonium, TCE, and uranium |
| **Portsmouth** | TCE and uranium |
| **Rocky Flats** | beryllium, plutonium, and uranium |
| **SRS** | TCE and tritium |

## The crust

Forces are continually changing the earth's crust, either by weather, climate, or volcanic events. Weathering processes are controlled by movement of water through surface layers, which in turn is determined by factors such as the amount of rainfall and evaporation, the topography, and the porosity and permeability of soil.

## Types of soil

Different types of soil affect the rate and mode of transportation of contaminants. Some common types of strata beneath the DOE sites include: bedrock, sand, gravel, limestone, basalt, and clay.

Bedrock is a layer of solid rock found beneath another layer consisting of soil, rock fragments, or gravel. Sand grains are formed as a result of weathering and are found as rounded or angular grains, varying in size. Gravel is typically of an intermediate size (in comparison to sand grains and boulders) and is composed of various kinds of rock. Limestone is primarily composed of calcium carbonate and is typically thick. Basalt is a fine-grained rock of volcanic origin, having originated in a molten state. As molten basalt cools, fine-grained rocks are formed. Clay is composed of fine-grained, earthy materials that have become plastic once in contact with water. The proportion of clay-like matter present also affects permeability and viscosity; greater amounts of clay will limit the permeability of materials into the subsurface. The surface and subsurface components at the thirteen DOE Sites vary and are listed in the table below.

| SITE | Surface and Subsurface Components at DOE Sites |
|---|---|
| **Fernald** | clay layer that contains silty sand and gravel |
| **Hanford** | gravel and basalt |
| **INEEL** | gravels, sands, silts, clays, and basalt |
| **LANL** | volcanic tuffs and lavas |
| **LLNL** | highly permeable interconnected coarse-grained sediments |
| **MEMP** | bedrock |
| **NTS** | alluvium, limestone, dolomites, volcanic tuffs, and lavas |
| **Oak Ridge** | limestone, shale, sandstones, and dolomites |
| **Paducah** | silty clay |
| **Pantex** | clay and sands |
| **Portsmouth** | gravel and sand, limestone, shale, and sandstone |
| **Rocky Flats** | gravel and bedrock |
| **SRS** | clay and sands |

In the early 1940s when decisions were made for the placement of these sites, basic issues of hydrology and geology were ignored. The geology of the sites has only been studied in detail in the last several decades. (Environmental concerns and public awareness has demanded a more rigorous approach at the weapons factories than was common in the first years of the Cold War. In addition, the science of hydrology and geology has matured in the intervening years.)

Also, all too frequently, DOE has been reluctant to fund a sufficient number of boreholes to adequately delineate the boundaries of existing strata or the extent of underground plumes of contamination. The depth to which boreholes are dug is another important factor. At Hanford, where there is concern regarding the depth to which cesium-contaminated wastes have migrated beneath the high-level waste tanks. The boreholes have not been drilled deep enough to provide a definitive answer.

It also should be noted that the difficulty of accurate predictions is intensified not only by the complexity of the underlying geology, but also by the long time-line during which safe storage is required. The geology of a site will change over the hundreds of thousands (and, in some cases, millions of years) that radionuclides and other toxins must be sequestered from the environment.

## Recommendations for protecting the aquifers

Initial reports on the spread of contamination offsite at nuclear weapons sites were optimistic and considerably in error. For example, in the 200 Areas at the Hanford Site, an estimate in 1953 reported the minimum time of migration offsite of contaminants to be 50 years. Another report written in 1959 estimated the time for travel to be between 175 and 180 years. In 1956, only 13 years after ground was first broken at Hanford, the first signs of groundwater contamination were discovered offsite, and in 1959, contamination was detected 9 miles away from Hanford.

Inaccurate predictions have been attributed to lack of technology and limited knowledge of behavior of how radioactive and hazardous materials behave beneath the surface.[23] Unfortunately, there is another factor at work here. The science of predicting the rate at which contaminants move through underlying strata is often seriously compromised by DOE's agenda which influences the parameters, methods and conclusions of geologic studies. Furthermore, there has been a disingenuous AEC/DOE policy to deceive the public by not releasing information on a timely basis and by covering up major accidents and leaks.

As a result of these complicated and inter-related factors, thus far, predictions in regards to the length of time it takes for contaminants to travel through aquifers and to spread into the surrounding environment have been inaccurate. The contaminants have spread through the soil and into the groundwater at many nuclear weapons sites much faster than ever expected. Without a firm comprehension of how water and contaminants move beneath the surface, the new predictions will also prove to be inaccurate.

Key to protecting aquifers is a rigorous monitoring regime that is based on well-funded, independent studies of the characteristics of each site. Geology and hydrology studies must be adequately funded and freed of the bias of the DOE, an agency that wants to downplay problems and gloss over errors of the past.

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[15] US EPA. "Types of Aquifers", 1999: <http://www.epa.gov/seahome/inject/src/aqtype.htm>.

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