West Virginia Environmental Protection Division of Water and Waste Management

Groundwater Program

Groundwater Program Remediation Guidance Document

February 2006

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A bulk fuel terminal with excessive hydrocarbon soil staining.

Groundwater Program Remediation Guidance Document

INTRODUCTION:

The Groundwater Program has been directly involved with the remediation of sites containing contaminated groundwater and soil throughout West Virginia. These sites, as of February 2006, total almost 200, and include old railyards, old refineries, fuel bulk terminals, above-ground fuel tank problems, and hydrocarbon spills, with contaminants that range from gasoline, diesel fuel, fuel oil, chlorinated solvents, and other materials, such as cow manure.

In many instances, the Groundwater Program is the sole DEP office in charge of the individual site; however, there are many occasions when the Program works in conjunction with other DEP offices, such as Environmental Enforcement or the Permitting Section. On occasion, the Program provides only advice to another DEP office or Federal agency. In general, the Groundwater Program's remedial sites do not fit under the authority of any other DEP agency, and the Program is the last recourse for remediation within the DEP system.

The authority for the Groundwater Program's remedial work is under Title 46, Series 12, *Requirements Regarding Groundwater Standards*. Although this authority is through the State's groundwater, the Program often works to remediate or remove contaminated soils, as the groundwater contamination (or the potential for groundwater contamination) cannot be completely cleaned up without such soil work.

TITLE 46, SERIES 12:

As previous stated, the authority of the Groundwater Program is derived from Title 46, Series 12, *Requirements Governing Groundwater Standards*. These regulations can be viewed in full at:

http://www.wvsos.com/csrdocs/worddocs/46%2D12.doc

HISTORY OF THE PROGRAM:

The need for a groundwater remediation program within the Office of Water Resources became apparent in early 1986 when a supervisor with the Industrial Branch of the Permitting Section visited an abandoned railyard in the northern part of the state. The railroad company in question wanted their NPDES permit revoked as the railyard had been destroyed by the 1985 Flood. The supervisor, however, was hesitant to allow this because he suspected there was significant subsurface contamination. A subsequent investigation (with a broken shovel found on site) found heavy-end hydrocarbon contamination just below the ground surface, and the need for a remediation program was born. This railyard, and then several other railyards throughout the state, were immediately added to the program.

The manpower required for this program soon outstripped what the Industrial Branch could supply, and the work was moved to the Groundwater Program in 1994. Since then, five employees of this Program have worked intermittently and full time on investigating and remediating both soil and groundwater subsurface contamination problems throughout the state.

As of February 2006, the Groundwater Program has worked on almost 200 sites, 25% of which are active at present. The Program has been the lead agency at 131 sites, provided advice at another 43 sites, and referred 22 sites to other DEP agencies. Ninety-four of these sites have required some kind of surface water or groundwater monitoring, 103 some kind of remediation, and we have issued 67 No Further Action Letters to date.

HOW THE PROGRAM WORKS:

Work on the Groundwater Program's remedial sites is often initiated by another DEP office or by a company's representative. On occasion, the Program provides only advice and the facility remains under the authority of the other DEP office, such as Environmental Enforcement, the Permitting Section, or Voluntary Remediation. This is particularly true if the site is a non-hazardous spill from a truck, in which case the site will almost always remain under the authority of Environmental Enforcement. On other occasions, the Groundwater Program may assume the responsibility for the site, and on still other occasions the site may be referred to yet another DEP agency, such as Compliance Monitoring or Voluntary Remediation. In short, the Groundwater Program oversees those contaminated sites that do not readily fall under the authority of any other DEP agency, and the Program is the final option for remediation for contamination that otherwise may not be regulated.

Once the site is suspected to have subsurface contamination—which is usually because of the facility history, a reported spill, surface staining, and/or a contaminated seep into a nearby surface water body—then a subsurface investigation is initiated. This investigation entails the use of either conventional soil borings, a geoprobe (or hydraulic punch), an excavator, and/or groundwater monitoring wells, and its purpose is to determine if the site is contaminated with certain compounds.

On occasion, a site is found to have no contamination; however, usually some sort of problem is discovered. A second subsurface (and sometimes a third) investigation is then required to determine the horizontal extent of the problem, as well as its depth, severity, contaminant phase, and the site geology.

Once this information has been obtained and the need for remediation determined, then a remediation system must be designed, installed, and operated at the site. These systems vary between the simple excavation of the contaminated soils, phytroremediation (the use of trees), vapor extraction, bioventing, bioremediation, pump and treat (which removes the contaminated groundwater, treats it, and then discharges it in some approved manner), high vacuum, air sparging (which is the addition of air to the subsurface), monitored natural attenuation, and/or the addition of oxygenating or reducing compounds to the subsurface.

Confirmation of the effectiveness of the remediation system is either obtained through groundwater monitoring, or—in the case of soil excavation—through confirmation soil samples collected around the sides and in the bottom of the excavation. A No Further Action letter is then issued by the Division of Water and Waste Management once the contamination has been successfully remediated.

THE DIFFERENCES BETWEEN THE VARIOUS DEP REMEDIATION PROGRAMS:

There are several different DEP offices that a site requiring remediation can be directed to. These include:

• *CERCLA:* This legislation, the Comprehensive Environmental Recovery and Compensation Liability Act, is what is commonly referred to as “Super Fund.” The Act works with abandoned hazardous sites where there is no generator or operator present . These sites are reported to the EPA, who then ranks them by environmental threat. The federal government then funds the investigation and clean-up, while at the same time attempting to locate a financially responsible party.

• *Enforcement:* The DEP Environmental Enforcement office is often the first group within DEP to encounter a contaminated site. As such, they often serve as a “traffic cop” and direct the site into which program it belongs. However, Environmental Enforcement can also choose to clean a site under their own authority. Sites in which they oversee often include small problems, such as truck spills, airplane crashes, or residential fuel oil accidents, most of which can be cleaned with a relatively minimum of effort and after-the-fact testing. Environmental Enforcement does not use risk assessment, and instead prefers to clean sites to a fixed soil or groundwater concentration.

- *Groundwater Program:* Because the Groundwater Program's authority is all inclusive, this program can handle any type of remediation problem. However, rather than attempting to control or remediate all the problem sites within the State, the Groundwater Program instead assumes the responsibility of those sites that do not fit under the authority of another DEP office. The Groundwater Program tends not to use risk assessment; it instead uses groundwater monitoring to determine if the site is clean, and it prefers to clean sites to a fixed soil or groundwater concentration.

- *LUST:* This office, the Leaking Underground Storage Tank program, works exclusively with underground gasoline and diesel tanks that have leaked and require removal and/or remediation. A licenced remediation specialist, who follows an explicit set of requirements, is required to perform the work. This program has no authority over residential fuel oil tanks.

- *Mining and Reclamation (Division of):* This office focuses entirely on remediation problems involving some kind of mining or quarrying. In particular, it concerns itself with the reclamation of old and present-day coal strip mines and of mine pool overflows.

- *Oil and Gas (Office of):* This office focuses entirely on remediation problems originating at oil and gas well sites. Its authority includes pipelines and pumping stations.

- *Permits:* This office, which is a part of the Division of Water and Waste Management, does not actually oversee remediation projects. It does, however, assume the responsibility for those sites with no subsurface contamination, but which have the potential to contaminate the environment. The office works by issuing a NPDES permit, which in turn has explicit requirements governing what the facility can and cannot do.

- *RCRA:* This legislation, the Resource Conservation and Recovery Act, defines the different classes of hazardous waste generators, and permits the treatment, storage, and disposal of such wastes. Only those facilities with hazardous waste need apply to this program for possible remediation.

- *Voluntary Remediation:* This program is commonly referred to as the "Brownsfield Program," and its purpose is to clean-up old industrial properties so that they can be reused. This program typically deals with properties that may be—or are in the process of being—sold, and it has statutes to safeguard both the buyer and the seller. Voluntary Remediation typically deals with larger environmental problems, and it often cleans the property to a less severe standard using risk assessment. A licensed remediation specialist is required to remediate sites within this program, and a company has to voluntarily choose to join the program. Usually, a property, once it has entered into this program, can only be utilized for commercial or industrial use after the environmental problem has been remediated. A company may choose not to join this program—usually because of the program's great many regulations, because the site does not require risk assessment, or because the company wishes to utilize the site after clean up for a residential use.

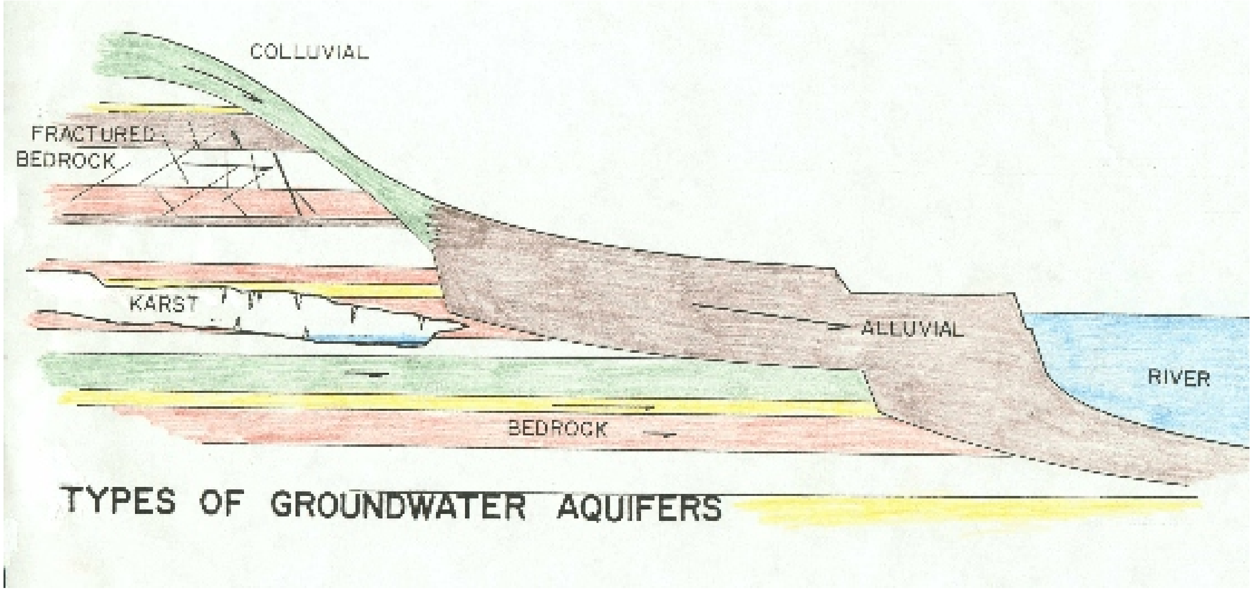
SITE GEOLOGY:

Many of the Groundwater Program's remediation sites are small and do not require extensive geological surveys. Often, regarding the groundwater itself, all that is determined is the depth of the upper-most groundwater zone, the flow direction of that zone, the gradient of the water table, if the upper-most zone is confined or unconfined, and if the upper-most zone is contaminated. Occasionally, the flow velocity of the groundwater is also calculated. In addition, several aspects of basic geology are considered, such as: what type of matrix makes up the aquifer (soil, alluvium, colluvium, bedrock, etc.), if the aquifer is karst, whether the aquifer is in a gaining or losing environment, and whether the aquifer is vadose or phreatic.

There are several types of aquifers in West Virginia. These are alluvial, colluvial, man-made fill, fractured bedrock, bedrock, and karst.

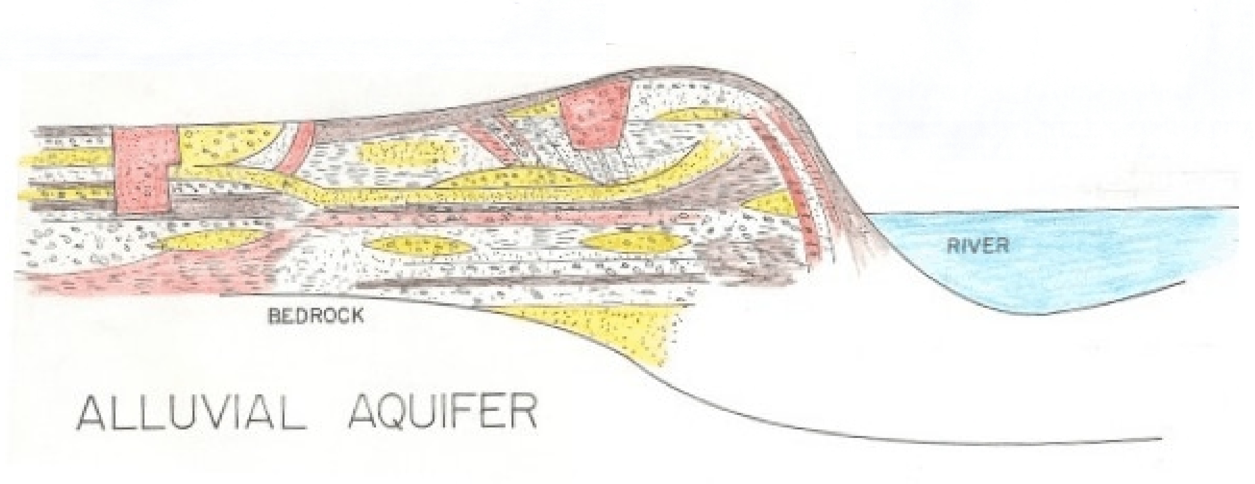
Many of the Groundwater Program's remedial sites are located along the State's present and historical transportation routes. This means that these sites are on the flat flood plains adjacent to the rivers. These sites are usually on alluvium, or water deposited sediments, which are layers of sand, gravel, silt, and clay. These aquifers are typically very shallow (usually less than 30 feet deep) and very heterogenic. As such, they contain many different materials with many different permeablities, and the groundwater velocities can vary between the very slow to the extremely fast. In general, gravel produces a faster water flow than sand, and sand produces a faster water flow than shales or silt.

In addition, these aquifers may contain old creek beds, river bars, sand dunes, and man-made trenches, all of which can all provide different groundwater velocities and directions. Groundwater flow is usually toward the nearby river; however, high river flow can occasionally reverse the groundwater flow and push it away from the river. With a small groundwater flow, the groundwater may move in stringers and follow areas



with greater permeability. With a greater quantity of water, the groundwater flow may become much more substantial and blanket-like, and can include flow routes that would be relatively impervious to groundwater movement during low-flow conditions.

An impervious material does not equal a matrix with no groundwater flow; it is actually a material with a ***slower*** water flow. Thus, one area may contain a series of aquifers and aquitards (which are zones of less groundwater flow and quantity); however, a move to a second area, where the first area's aquifers do not exist, and the first area's aquitard may become the second area's aquifer. In short, the aquitard-turned-aquifer is the second area's water-producing zone (although slowly), as the better zones do not exist.



It should also be remembered that the condition of the groundwater flow is always changing. Like surface streams, the groundwater flow is either increasing or decreasing (and the water table going up or down), depending on the amount of water input at any one particular moment. This means that an aquifer can be small and move in stringers at one point in time, such as during a dry summer, but increase and become a blanket-like flow during a wetter period, such as in the spring. Also, a winter freeze can cause the water input into the aquifer to decease, while snow melt can cause it to increase. The amount of vegetation can also make a great difference to the amount of water in both the surface streams and in the groundwater aquifers. In the spring, before the plants "come alive," both the surface streams and the groundwater aquifers may contain a great deal of water. However, as soon as the spring flowers begin to bloom, the leaves come out on the trees, and the grasses begin to grow, then the surface streams decrease significantly in volume—as does the groundwater aquifers. And this can happen incredibly rapidly, even in the space of a single week.

Colluvium, at its simplest, is the soil, small rocks, and large rocks that result from the chemical and physical breakdown of hillsides. Groundwater quantity and flow can vary greatly in colluvial aquifers, because of its many different subsurface properties; however, the groundwater usually moves down the hillside. The amount of groundwater is often less than in alluvial aquifers and, because of this, colluvial groundwater is often found in thin stringers.

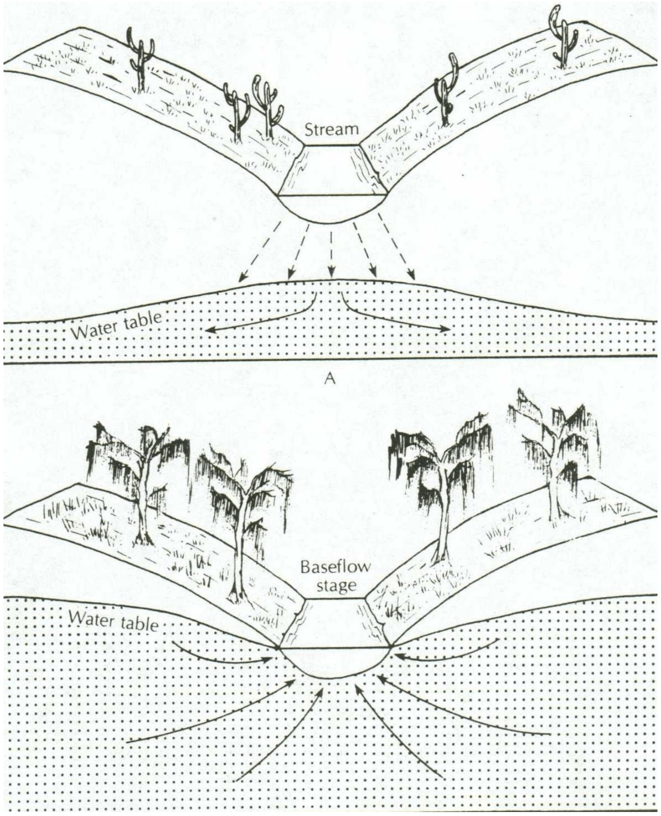
Man-made fill is rock, soil, gravel, coal, slag, red dog, etc. that has been placed to level or raise a given area. This fill can be in different layers, and it can be trenched for underground conduits. It can also be placed in thin layers on top of alluvium or colluvium. Because of this, man-made fill is also very heterogenic, and groundwater directions and velocities can vary greatly. The flow can be either blanket-like in nature if there is enough groundwater, or it can move in stringers if there is less groundwater.

In bedrock, unless the water is moving along bedding planes, the groundwater flow is usually very slow. Because of this, producing aquifers within the actual sandstones, shales, and limestones within the state are not as common as many people think. In addition, because these aquifers are deeper underground, the Groundwater Program has only a few sites with contamination that is purely within a bedrock aquifer. In should be noted, however, that these are aquifers that require decades and centuries to be contaminated, and they also require equally large amounts of time to be remediated.

Fractured bedrock is another medium that can carry small or large quantities of groundwater. The governing factors here are the size and shape of the fractures, as well as how continuous they are. These aquifers can be very important because a heavier-than-water contaminant can move down through a shallower aquifer and become trapped within the fractured bedrock. This contamination can then be virtually impossible to remove or remediate.

Of all West Virginia's aquifers, those that develop in karst are the most sensitive and are some of the easiest contaminated. In short, karst is the dissolution of a soluble bedrock, such as limestone. Rain water picks up carbonic acid in the soil and becomes slightly acidic. This weak acid dissolves out the predominately alkaline rock, forming voids and caves. The water is usually then channeled through the bedrock, resulting in fast water travel times (and no time for the contaminant to degrade) and little or no filtration. In other words, any contamination entering a karst sinkhole is rapidly moved through the cave to a spring, and then reappears in much the same concentration as when it disappeared below the ground surface.

Karst, in West Virginia, is usually found only in the eastern part of the state. It is a terrain typified by underground streams, few (or no) surface streams, sinkholes, caves, and large springs. In West Virginia, coal and limestone were not deposited in the same areas. This is purely an accident of deposition, but where there is coal, there is no karst, and where there is karst, there is no coal. This rule is not true elsewhere in the Appalachians.

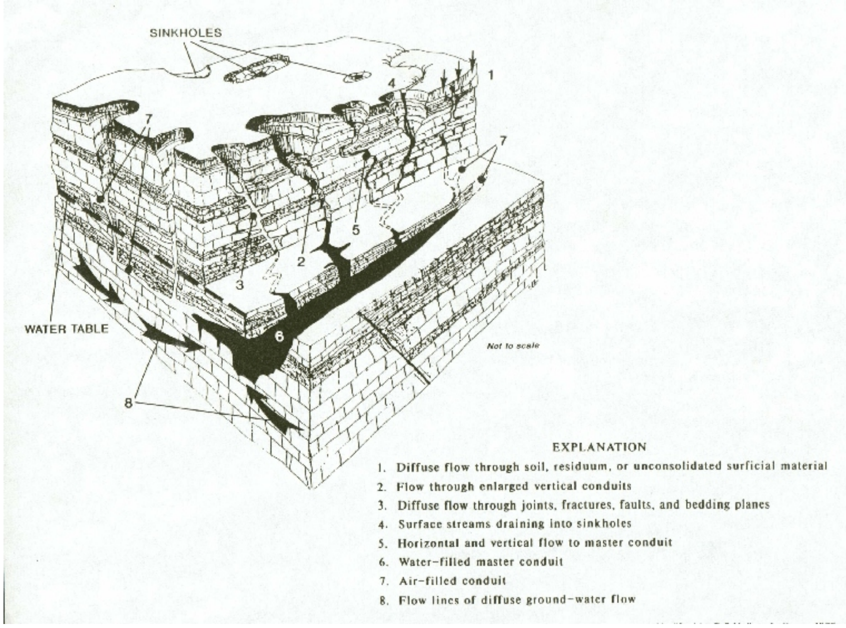


A losing stream (top) and a gaining stream (bottom).

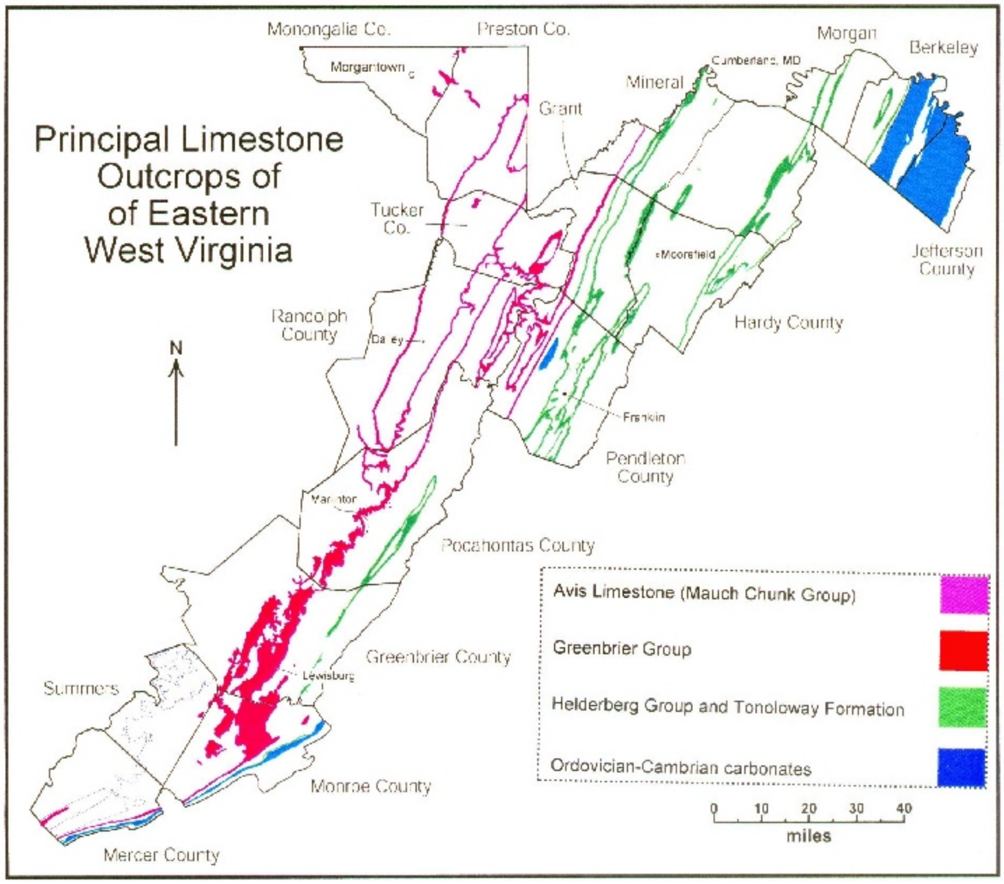
Mined coal areas and karst do have one thing in common—they are (for the most part) the only areas within West Virginia where one finds losing streams. Usually, because of the State's high rainfall, the state's surface streams are gaining in nature. A losing stream is a surface stream that loses water to the groundwater aquifer, while a gaining stream is a stream that gains water from the groundwater.

There are three types of karst areas in West Virginia. These are:

- There are large plateaus of limestone in the southeastern part of the state, where the groundwater moves in huge conduits within very large caves. The water can travel many miles underground, often with many



A schematic of a block of karst.



converging flows, and resurges at large springs. These plateaus are found in eastern Greenbrier County, Monroe County, and in the Little Levels area of Pocahontas County, and they contain the state's largest caves, the largest cave passages, the largest springs, and the largest spring basins. An example of one of the large karst basins is the Davis Spring Basin of Greenbrier County.

- There are mountainside exposures of limestone in the east-central part of West Virginia, where surface water moves down the mountain until it encounters the limestone. The water usually goes underground then, flows parallel to the mountainside, and resurges at springs located in the deeper hollows. This type of karst is found along East River Mountain in Mercer and Monroe Counties, and in the mountainside outcrops north Little Levels. Examples are the Greenbrier limestone exposures on either side of the Tygard River Valley, on the east side of Shavers Mountain, and in the Dry Fork Valley of Randolph County.

- There is a large karst plateau located in the lower Shenandoah Valley in Berkeley and Jefferson Counties. Here the water sinks in the area's many sinkholes, but—because the carbonates are steeply dipping and highly fractured—the groundwater flows diverge and follow small fractures in many different directions. Groundwater flow is slower, often taking months, and the water ultimately reappears at large springs. This karst area, which may be the largest in the State, is divided in two by the folded shales of the Massanutten Syncline.

THE PROPERTIES OF CONTAMINATION:

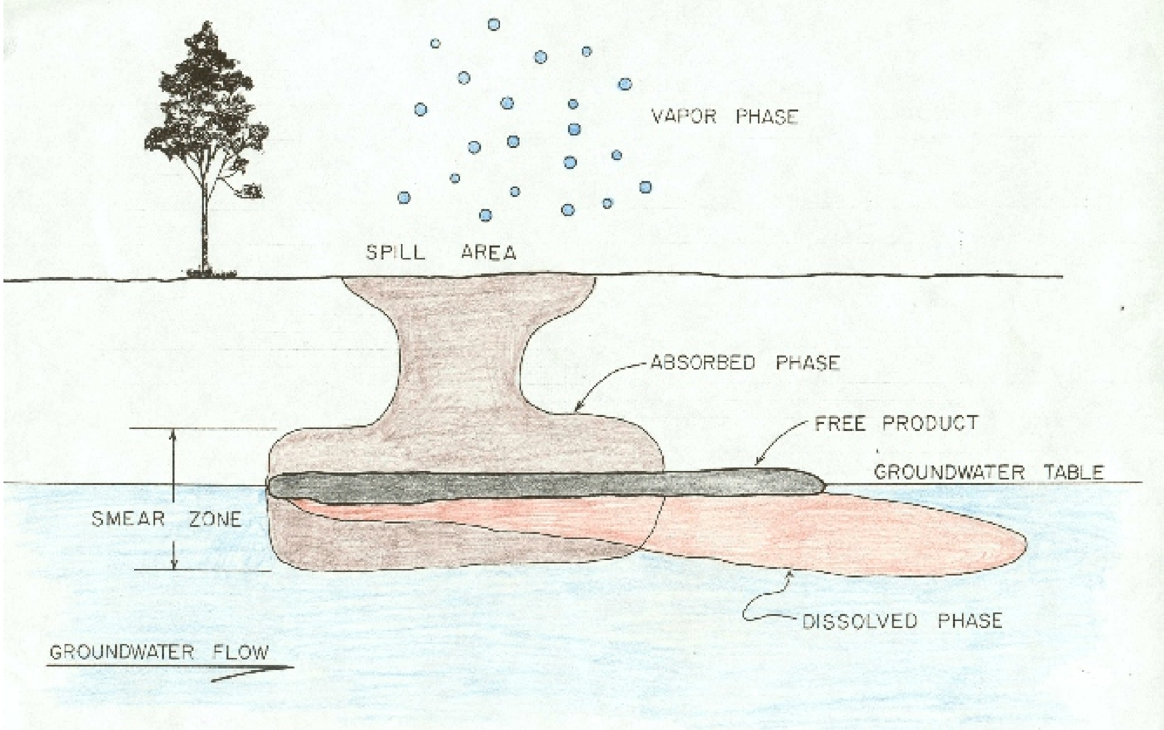
When investigating or remediating a given facility, there are several items to be considered regarding the contaminant itself. These are: the type of contamination, its properties, the concentration of the contamination, and the phase of the contamination.

Simply put, the type of contamiantion is what compounds or groups of compounds have contaminated the site. These can be hydrocarbons, such as TPH-GRO, TPH-DRO, TPH-ORO, BTEX, or PAHs; chlorinated solvents, such as PCE, TCE, or DCE; metals, such as lead or mercury; or an "unique" material or compound, such as animal manure. A explanation of these abbreviations is as follows:

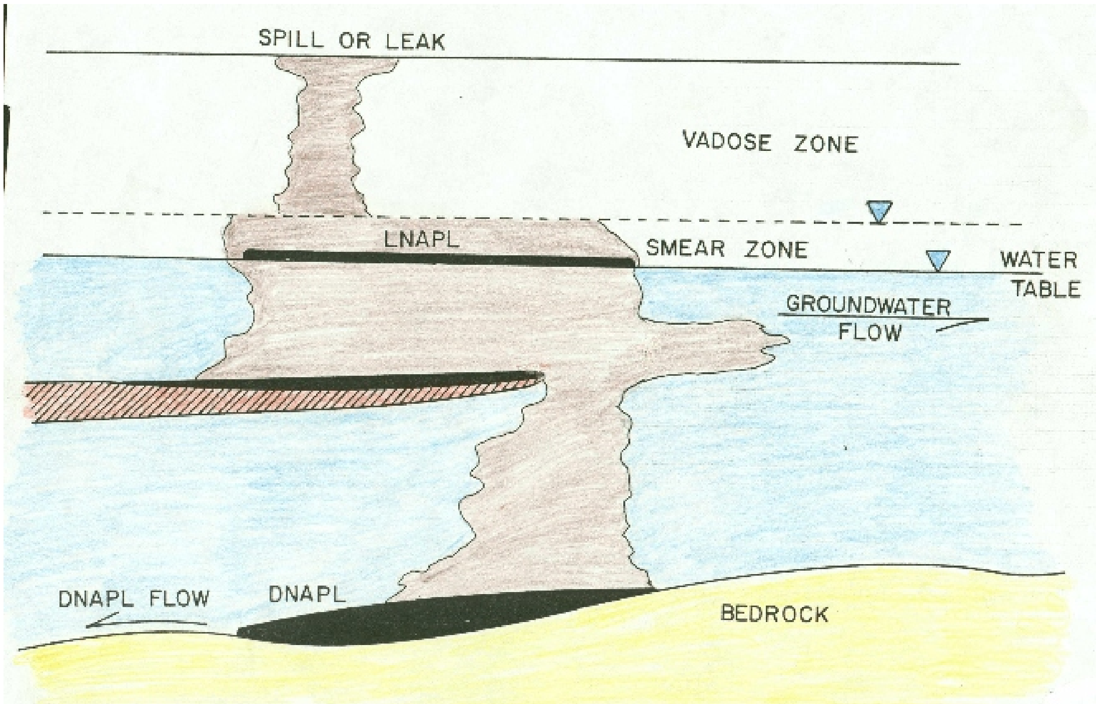
Abbreviation	*Compound*	*Type*
TPH-GRO	Total Petroleum Hydrocarbons Light-weight Gasoline-Range Organics	Hydrocarbon
TPH-DRO	Total Petroleum Hydrocarbons Medium-weight Diesel-Range Organics (includes kerosene and fuel oil)	Hydrocarbon
TPH-ORO	Total Petroleum Hydrocarbons Heavy-weight Oil-Range Organics	Hydrocarbon
BTEX	Benzene, toluene, ethylbenzene, and xylenes The four common compounds found in gasoline.	Hydrocarbon
PAHs	Poly Aromatic Hydrocarbons, which are common compounds found in coal and heavy-end hydrocarbons.	Hydrocarbon
MTBE	Methyl tertiary-butyl ether	Oxygenate
VOCs	Volatile Organic Compounds	Solvents
PCE	Tetrachloroethene	Solvent
TCE	Trichloroethene	Solvent
1-1-DCE	1-1-Dichloroethene	Solvent
c-1-2-DCE	cis-1-2-Dichloroethene	Solvent
t-1-2-DCE	trans-1-2-Dichloroethene	Solvent
1-1-DCA	1-1-Dichloroethane	Solvent
1-1-1-TCA	1-1-1-Trichloroethene	Solvent

It is important to know the type of contaminant, because some compounds, such as those associated with hydrocarbons, are lighter than water and will float on the surface of the groundwater. These are called LNAPLs, or Light Non-Aqueous Phase Liquids (liquids that are not water), and they will move downstream with the groundwater flow. Other compounds, such as solvents, will sink through the groundwater layer, find their way to the top of the first impermeable layer, and then follow that layer's surface downward with gravity. These are called DNAPLs, or Dense Non-Aqueous Phase Liquids.

It should also be noted that some compounds, such as the four BTEX compounds have relatively high water solubilities, while the PAHs and heavy-end hydrocarbons are relatively insoluble. Compounds with low water solubilities tend to bind on the soil. Then the groundwater, as it moves vertically up and down within the



THE CONSTITUENTS OF A HYDROCARBON SPILL



DNAPL FLOWS

soil, can smear these contaminants over a significant vertical area. This smear zone can become the source area for additional groundwater contamination, once the original contamination source is removed.

Some water solubilities and densities for common contaminants are:

Compound	*Density*	*Water Solubility*
Benzene	0.8786	1780 mg/l at 15˚ C
Ethylbenzene	0.867	140 mg/l at 20˚ C
Toluene	0.867	470 mg/l at 16˚ C
o-Xylene	0.88	175 mg/l at 20˚ C
m-Xylene	0.864 at 20˚ C	
p-Xylene	0.86 at 20˚ C	198 mg/l at 25˚ C
MTBE	0.74	4800 mg/l
Acenaphthene	1.069	
Acenaphthylene	0.899	39.3 mg/l at 25˚ C
Fluorene		1.9 mg/l at 25˚ C
Naphthalene	1.152	30.0 mg/l
Phenanthrene	1.025	1.6 at 15˚ C

The five PAHs shown—acenaphthene, aenaphthylene, fluorene, naphthalene, phenanthrene—while being relatively insoluble in water, are the five most soluble PAHs.

(From: *Handbook of Environmental Data on Organic Chemicals*, Second Edition, Karl Verschueren, Van Hostrand Reinhard Company, 1983.

Contaminant phase is how the contaminant compound "divides" itself in the environment. Usually, the contaminant's phase is one of the following four conditions:

- Free phase (or free product), which is a liquid hydrocarbon layer of the contaminant that may be found on top of the groundwater table,

- Dissolved phase, which is the contamination that dissolves in the groundwater,

- Absorbed phase, which is the contamination that adheres to the soil, and

- Vapor phase, which is the contamination that vaporizes into the atmosphere.

It should also be noted that a thin emulation phase can be produced, if a investigation or remediation technology is unfortunate enough to “stir up” a free product layer that is on top of the groundwater table. This phase is extremely difficult to remove or remediate. Fortunately, this phase is also extremely difficult to produce, and cannot be produced by most subsurface work.

In addition, there is also a test procedure that produces a leachate from the soil, and then the liquid leachate is analyzed for the contaminants of concern. This is called a TCLP, or Toxicity Characteristic Leaching Procedure, and it is performed to determine if a contaminant is a hazardous waste. This test is usually performed by the Groundwater Program only to determine if the contaminant is hazardous and thus subject to the regulations and Authority of the Division of Water and Waste Management, as the Groundwater Program has no authority over hazardous waste. The TCLP limits of many common contaminants can be found in 40-CFR-261.24.

The concentration of the contaminant is also very important, as no compounds are a threat to humans or the environment in small concentrations. The concentrations that the Groundwater Program uses both to initiate soil and groundwater remediation and as end-points to determine the success of that remediation are shown below:

GROUNDWATER AND SOIL LIMITS				
Parameter	*Groundwater*		*Soil*	
TPH-GRO	1.0 mg/l	DEP Action Level	100 mg/kg	DEP Action Level
TPH-DRO	1.0 mg/l	DEP Action Level	100 mg/kg	DEP Action Level
TPH-ORO	1.0 mg/l	DEP Action Level	100 mg/kg	DEP Action Level
Benzene	5.0 µg/l	46-CSR-12	50 µg/kg	DEP Action Level
Ethylbenzene	0.7 mg/l	46-CSR-12		
Toluene	1.0 mg/l	46-CSR-12		
Total Xylenes	10.0 mg/l	46-CSR-12		
Total BTEX			10 mg/kg	DEP Action Level
MTBE	20 µg/l	DEP Action Level		
Dissolved lead	15 µg/l	46-CSR-12	5 mg/kg	DEP Action Level
Naphthalene (PAH)	20 µg/l	DEP Action Level		
Benzo (a) pyrene (PAH)	4 µg/l	46-CSR-12		
Total PAHs			1 mg/kg	DEP Action Level

Those limits set by Title 46, Series 12, *The Requirements Governing Groundwater Standards*, are set by the West Virginia legislature and, as such, cannot be deviated from. However, those limits that are DEP Action Levels are guideline concentrations used by both the Groundwater Program and the Office of Environmental Remediation, and these can be adjusted site by site, as needed.

THE SITE INVESTIGATION:

It is almost always necessary to perform an initial investigation to determine if a site is contaminated. The purpose of this investigation is to find out what contaminants may be present at what locations at the site. This is actually a simple process, as some sites are known to have used gasoline, diesel fuel, or fuel oil, and many others sites used different compounds at obvious locations. In addition, there may be excessive soil staining, obvious infrastructure that contributed to the problem, or old analytical data available for the site. Once the initial site investigation is completed, it is possible to proceed directly with remediation (if required). However a second and even a third site investigation is usually required to determine the horizontal extent, depth, phases, and severity of the contamination.

There are several different kinds of sites that require investigations. These include:

- *Railyards:* It is important to analyze the soils and groundwater at any location where fuel was handled, such as around locomotive refueling areas, tank car and truck fuel unloading areas, any treatment facilities (such as an oil-water separator), and around any fuel lines or bulk tanks. A wide range of hydrocarbons should be sampled for, and it may also be necessary to sample for some metals. In addition, if the railyard has (or has had) a maintenance shop, it is important to locate any areas where chlorinated solvents might have been disposed of and sample these locations for the PCE-TCE family of compounds. Subsequent investigations need not sample for those parameters not found during the initial investigation.

- *Bulk Terminals:* It is important to analyze the soils and groundwater within any diked-in areas, around any treatment facilities, around any pumps or buried fuel lines (particularly around buried lines with 90˚ bends), and where trucks, rail cars, or barges may have loaded or unloaded fuel. The analytical testing can be tailored toward the individual hydrocarbon handled, or toward a wide range of hydrocarbons—such as TPH-GRO, TPH-GRO, TPH-DRO, BTEX, and a suite of PAHs. On occasion, and in particular at sites were old fuels may have been handled, it is necessary to search for total and dissolved lead. For newer sites, it is prudent to sample for MTBE. Subsequent investigations need not sample for those parameters not found in the initial investigation.

- *Old refineries:* These sites can be difficult. The sample parameters should include a wide range of parameters, and the sample locations should include those areas within the facility where problems may have developed. It is also important to place some sample locations at “random” points throughout the facility to check for unobvious contmainated areas, and it is important to sample for total lead, dissolved lead, and MTBE.

- *Leaking tanks (buried or aboveground) and small spills:* It is important, at these sites, to locate the tank or the spill area. Sample locations should be placed around the area of concern (both horizontally and vertically), and the analytical tests can be tailored for the exact contaminant. Underground gasoline and diesel tanks should be referred to the Leaking Underground Storage Tank (LUST) Program, as the authority to remediate these sites rests with that office.

There are many different tools that can be used in the preliminary (and in subsequent) site investigations. These are:

- *Geoprobe-type device:* This is a hydraulic punch that may or may not include a mechanical or pneumatic hammer. Simply put, the geoprobe shoves a small-diameter tube or pipe into the ground and a soil and/or groundwater sample is collected. Additional pipe can be added to the top of the “drilling string” so that deeper horizons can be reached. The entire drilling string must be retrieved to collect the soil samples, which are often contained inside an interior plastic tube to prevent cross contamination. The soil samples are opened on site so that the geologist can describe the soil section and so that a analytical sample can be collected for the laboratory. VOC samples should be contained within the plastic (or within a metal sleeve), so that their vapors will not escape. In addition, an interior metal sleeve can be slid out of the way, once the drilling string is in the ground, and this allows the collection of soil or groundwater samples at a precise vertical location without contamination from shallower horizons.

  The advantages of geoprobes are that they are a small unit that can be easily maneuvered around site (especially a crowded site) and that the cost of the sampling is relatively inexpensive. The disadvantages of a geoprobe are that they can not sample as deep as conventional drilling rigs and that it requires “a less hard” horizon to halt their penetration. Geoprobes are usually only used on sites with shallow contamination, as they usually cannot go very deep; however, some geoprobes have been used in the Ohio Valley flood plain to obtain samples as deep as 90 feet.

A truck-mounted geoprobe at work.

There are two theories regarding the collection of groundwater samples via a geoprobe: one is that the geoprobe will always carry a little contamination downward with its pipe and that it collects a “muddy,” “more-contaminated” sample, and the other is that the geoprobe collects a more precise groundwater sample, one that is not subject to the dilution that may occur in a groundwater monitoring well with a relative long screen horizon. Both theories result in a higher contaminant concentration in the groundwater, but one theory is a negative statement on using the geoprobe while the other is a positive statement. It should also be noted that it can be very hard to produce a top-of-groundwater map with geoprobe sample locations, as it is difficult to precisely locate the top of the wellhead vertically.

- *Split spoon auger:* This is a more conventional technique than the geoprobe, and is just as effective. Essentially, a hollow auger is powered into the subsurface and the soil sample is collected in the hollow interior of the auger. Additional augers can be added to the top of the “drilling string” so that deeper horizons can be reached, and the entire drilling string must be removed from the ground to collect a soil sample. The auger is opened into two halves using a wrench (this is why it is called a split spoon), and the soil column described and a sample collected. Augers usually have more power than geoprobes and can drill to greater depths and through harder horizons. They are, however, more expensive and less mobile. Split spoon augers can be used to collect groundwater samples; however, this is very difficult and the resulting sample is often very dirty with loose soil particles. Plus, it is difficult to precisely locate the top of the wellhead and produce a top-of-groundwater map using a split-spoon auger.

A split-spoon auger in use. The auger itself can be seen in front the driller with the stripped shirt.

- *Hand sampling:* There are a myriad of methods of collecting soil samples by hand. One way is to simply take the sample from the ground surface, which works well at sites with surficial soil staining. Another way is use a shovel and dig down a few inches or feet. A third method entails using a device to drive a steel probe into the ground. This probe is retrieved and the soil sample removed from its interior. A fourth way is to use a hand auger, where one or two persons provide the muscle power to turn the device. A last method is to use a hand-held power auger. This is easier on the operator and will allow for deeper and easier subsurface penetration. The advantages of these devices are that they are very inexpensive and can be used in areas not accessible by larger equipment mounted on a tractor or truck. Their chief disadvantage is their limited penetration ability, both in depth and power. It is also often possible to collect a groundwater sample using many of these techniques and devices.

- *Drilling rigs:* On occasion, it is necessary to use a drilling rig to collect soil and/or groundwater samples. These rigs can have a rotary bit, where only the drill cuttings are collected, or they can have a diamond bit, where soil or rock cores are collected. It is sometimes necessary, with these rigs, to pull the entire drilling string from the hole to collect the core, or they may be wire line drilling rigs, where a metal core barrel is inserted into the drilling pipe. The soil sample is then collected by pulling the wire and the core barrel up through the drill pipe, and the core barrel is removed from the drill string and the soil column is shoved out the barrel with a metal ramrod. The soil column is then described and a sample collected. These drilling rigs are usually more expensive than a geoprobe or split-spoon auger, however, they can reach depths unattainable by the other equipment and they can drill through much harder horizons.

The disadvantages of drilling rigs are their expense, and that they are large and can be hard to move around a crowded facility. They also contain a tall mast, and this can cause problems at a site with a large number of overhead wires. A groundwater sample can be collected using a drilling rig; however, this sample shares all the disadvantages of collecting such a sample with a geoprobe or split-spoon auger. Usually, if an auger or drilling rig is used, a properly-constructed groundwater monitoring well is installed in the borehole once the soil samples have been collected.

- *Excavator:* A back or track hoe can be used to excavate a potentially contaminated area, and then soil samples are collected from the walls and bottom of the excavation. This technique has several advantages, and one overcomes a major problem with all geological assessments. This is that almost all geological assessments are completed by punching holes into the subsurface and then assuming that the horizons and contamination is consistent between the holes. However, when an excavation is dug, it is then possible to see a large expanse of the subsurface, ascertain what geological horizons are continuous, and collect soil samples from where the contamination appears the worst. In short, the geologist can see much more of the geology in an open excavation, as they provide major insights into the subsurface strata and contamination. All the soil removed from an excavation should be placed on plastic and under plastic, at least until it has been tested and proved uncontaminated. This is to prevent the soil from contaminating both the groundwater and/or stormwater.

- *Soil sampling:* Almost all the soil sampling methods produce a vertical column of soil, usually about two feet long. This composition of the sample is described by the on-site geologist, who also notes any contaminant staining and/or smell. Occasionally, the sample is also placed under a black light, as this will cause any hydrocarbon to phosphorescence.

The soil sample is then split laterally, and half is placed in labeled plastic bags. The geologist next uses a PID or FID meter to determine which sample contains the highest VOC concentration. A PID is a photo-ionization detector and a FID is a flame-ionization detector meter. Both should be calibrated before use. These detectors have a flexible probe on one end, and this is shoved inside the plastic bag. All of the soil data (the description of the composition, contamination information, and PID or FID data) is recorded and used to determine which sample should then be sent to the laboratory for analysis.

Usually one soil sample is send to the laboratory, but occasionally more contamiantion is found and two samples are sent. If no contamination is found, then a representative sample, usually from just above the groundwater table (and within any potential smear zone), is sent to the laboratory. It is very important to send this representative sample, because this provides hard documentation that the location is not contaminated. Soil samples are transported on ice with the proper chain-of-custody forms. The laboratory should be contacted before hand, so that the proper containers, etc. can be obtained and used.

No matter which drilling or sampling technique is used, all the soil sampling equipment should be properly decontaminated between sampling, and all the drilling equipment (and excavator buckets) should be decontaminated between sample locations. Usually this entails washing the equipment with a bio-degradable soap and then rinsing it with distilled water. In addition, nitrite gloves should be used to collect each soil sample and disposed of properly between each sample collection.

A geologist measuring the soil sample prior to describing it. A fluorescein light box is in the foreground of this picture.

• *Soil gas surveys:* These are surveys, usually performed on some type of grid, where a probe is inserted into the ground and the volatile organic gas within the soil measured. The probe can be driven in by hand, inserted using a hand-driven steel sampling device, or inserted using a geoprobe. These surveys work well with recent contamination and contaminants that vaporize easily; they do not work at all on old problems with heavy-end hydrocarbon. Put another way, a soil gas survey may accurately delineate a recent spill of gasoline, which is a volatile; however, it may completely overlook an old spill of diesel fuel, which is not only a semi-volatile, but has had time for the contaminant's vapor phase to have completely dissipated.

In addition, soil gas surveys do not locate the contaminant itself, but rather the contaminant's vapor plume. For example, a chlorinated solvent may filter down through the subsurface, finding its way through permeable lenses, and moving some distance away from the original source area. The vapor phase of the contaminant then works its way back up through different lenses, now moving away from the liquid plume. It is this vapor phase that the soil gas survey locates, not the liquid plume and not the original source area. Thus soil gas surveys are a tool that should be used with some discretion.

• *Geophysical surveys:* These are non-traditional investigative methods that require some kind of electronic equipment. Geophysical surveys can include electrical resistivity, electrical magnetic, seismic refraction, seismic reflection, micro-gravity, and borehole analysis and logging. Some, such as micro-gravity, require a single receiver, while others require multiple receivers that are often placed in arrays.

All have advantages and disadvantages, and all are non-invasive techniques that should be confirmed by drilling or a geoprobe. Some, such as electrical magnetic can only be used to locate metallic objects underground, while others—such as electrical resistivity, seismic refraction, and micro gravity—can be used to locate underground voids or caves. None, other than direct boring, can locate subsurface contamination, but all can provide important clues where that contamination can be found. The functional depth of each method can vary because of the equipment used, the individual subsurface conditions, and the spacing of the receiver array. In addition, many of the surveys require some sort of radio or sound source, and some methods are affected by the moisture and clay in the ground.

Still, a geophysical surveys can be relatively inexpensive, and they have an important advantage over traditional investigative methods. Unlike a geoprobe or soil boring, where ***only*** points of data are collected and assumptions made about the conditions in between, geophysical surveys provide lines of data—and less assumptions are then required.

A micro gravity survey.

• *Groundwater monitoring wells:* It is necessary, at many remediation sites, to install groundwater monitoring wells. Occasionally, a company may even wish to install these wells during the initial investigation, as they produce quality groundwater samples, allow for repetitive data to be collected, and allow a top-of-groundwater map to be constructed. All groundwater monitoring wells in West Virginia must be installed by a West Virginia certified well driller in accordance with Title 47, Series 59, *Monitoring Well Regulations*, and Title 47, Series 60, *Monitoring Well Design Standards*.

Well locations are selected to be down-gradient of potentially contaminated areas, and the wells' screened intervals are placed within the horizon of concern. This is often, and particularly for LNAPLs, across the water table. A background well is often required, which is located up-gradient of the contaminated area. This well will provide information as to what the groundwater quality would be, if the site was not contaminated, and it also allows for the discovery of any up-gradient contamination. The groundwater monitoring wells should be sited so that they form triangles, not

Drilling a groundwater monitoring well with an air rotary drilling rig.

straight lines, as this will allow for more precise top-of-groundwater maps to be constructed.

After installation, the wells are developed to remove fine silt and clay partials from their interiors (this is completed by surging water or air into the well), and the wellheads are surveyed to a common datum. The depth to the groundwater and any free product thickness is measured to the nearest hundred of a foot, and the resulting groundwater elevations plotted on a site map and the surface of the groundwater table contoured. Groundwater monitoring wells can also be used to determine if the aquifer is confined or unconfined, as a confined groundwater zone will cause the water in the well to rise above the horizon where it was encountered. If the groundwater is confined, the groundwater surface should properly be called a piezometric surface. If the groundwater is not confined, then the resulting surface may be called a piezometric map or a top-of-groundwater map.

Once the groundwater elevation and free product thickness has been determined, at least three well volumes of standing water is removed (or purged) from the well. This is done so that the subsequent groundwater sample is collected from formation water, not water that has been sitting in the well. Purging is completed by using some type of pump or by manually bailing the water. The purge water is collected and, if the groundwater sample from that particular well is found to contain no contamination, then the purge water can be poured on the ground. If the sample is found to be contaminated, then the purge water must be properly disposed of, either on or off site.

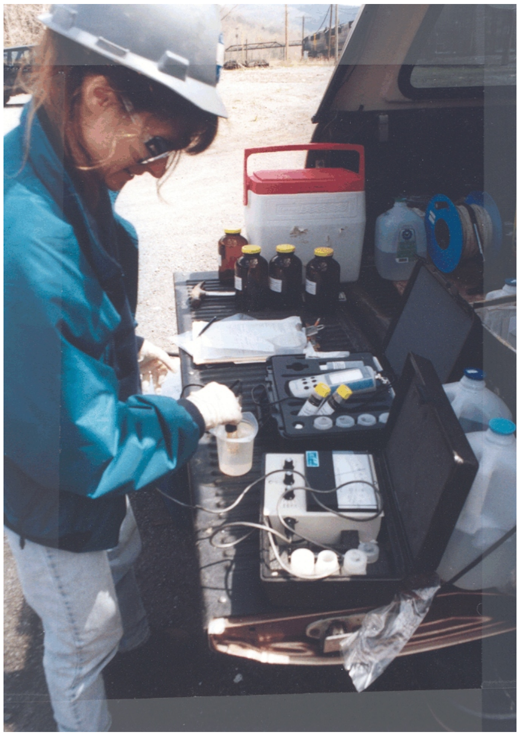
The well is considered to be sufficiently purged if the pH, conductivity, and temperature of a subsequent well volume are all found to be within 0.1 Standard Unit, 10 µmhos/con, and 0.5˚ C of the previous well volume. Once the well has been appropriately purged, then the groundwater samples can be collected. This is usually achieved by using a dedicated bailer that is stored inside the well between uses or disposed of after its use. A written record is documented, and this should include the person collecting the sample, the day and time, any groundwater odors, the groundwater appearance, and the field pH, conductivity, and temperature.

It is also important to decontaminate all sampling equipment between the

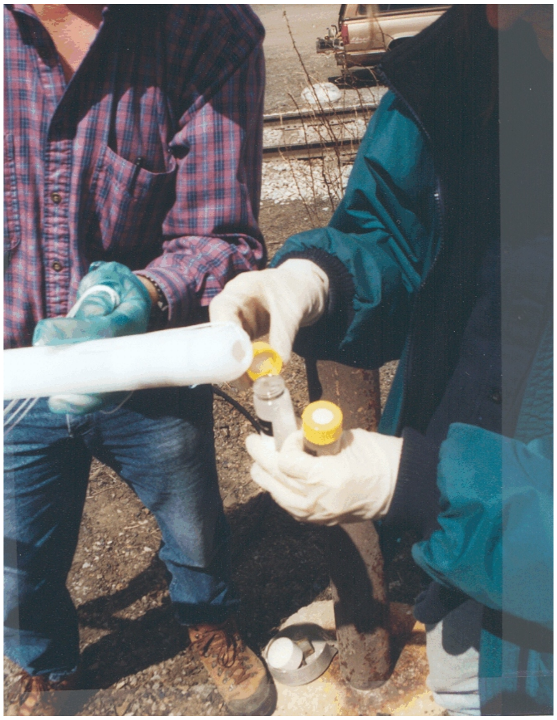
For more information on sampling groundwater, please contact the Groundwater Program (Division of Water and Waste Management) for a copy of the *Quality Assurance and Quality Control Plan and Standard Operating Procedures for Groundwater Sampling, 68 pages*, 2002.

Measuring the depth to groundwater in a groundwater monitoring well.

Bailing off the purge water in a groundwater monitoring well.



Measuring the field pH, conductivity, and temperature of the well water.



Collecting a BTEX groundwater sample.

collection of the groundwater samples, and it is important to use nitrite gloves and to dispose of those gloves between sample collection.

The most important factor regarding a proper groundwater monitoring well program is that it allows the groundwater to be sampled and its surface mapped on a regular basis and at consistent locations. This allows long-term trends in the free product thickness, the groundwater contamination concentrations, and the groundwater flow direction to be documented.

- *Surface water sampling:* Occasionally, if the site is adjacent to a surface stream, it is necessary to sample this stream. Samples should be collected both above and below the facility to determine if the stream is contaminated by the facility of interest or by another, upstream site.

- *Spring sampling:* It is also sometimes necessary, particularly in karst areas, to sample the water resurging from nearby springs. Groundwater monitoring wells are often ineffective in karst, as they do not intersect the hard-to-find underground conduits. However, karst springs can be ***very*** difficult to sample, as the contamination tends to flow out of the spring only during high-water events, and it is extremely hard to be at the spring at the correct moment.

- *Dye tracing:* Occasionally (and usually in karst), dye tracing is employed to locate the groundwater basins and determine its flows. First, dye traps are placed in the receiving streams to determine if there is any background concentration of the dyes to be used. Once this has been achieved, the traps are replaced with clean traps, and a dye is selected and placed in an upstream sinking stream or sinkhole. Occasionally, the dye is placed in groundwater monitoring wells; however, because these wells are seldom located in the conduit flow common to most karst, it is very hard to get the dye to flow out of the well, even after the addition of large quantities of water. The traps are then collected, usually on a weekly basis, and transported (with the proper documentation) to a laboratory.

The dyes themselves are harmless to both the humans and animals, and the traps are small pieces of screen mesh, folded so that they are about one by five inches in size, secured with stables, and then placed in the receiving stream using heavy-duty fishing line or wire. There are two kinds of dyes (fluorescein and rhodamine, and Direct Yellow and optical brighteners), and there are thus two kinds of traps, one containing activated charcoal and the other natural unbleached cotton. Once in the laboratory, the charcoal traps are eluted with alcohol, placed in a scanning spectrofluorometer, and the standard fluorescein and rhodamine wave peaks searched for. The cotton traps are observed under an ultraviolet light. The cotton will show a bright yellow if it has come in contact with a Direct Yellow dye, and it show a bright bluish-white fluorescence if it has come in contact with an optical brightener. Optical brightener dyes cannot be used if the water is contaminated with laundry detergent.

ANALYTIC TEST METHODS:

While there might be some purpose in including a table of preferred EPA test methods in this report, these methods change and are improved upon on a regular basis. Therefore, any test method provided by this report could be out of date.

It is thus recommended that anyone needing a given test method should contact the laboratory in question and ask them what is the most up-to-date and the best method that should be used. This laboratory can, at the same time, provide information on what equipment and physical method is required to collect the soil and/or groundwater samples.

There are several points, however, to keep in mind regarding analytical test methods. These are:

- All laboratory work within West Virginia ***must*** be completed by a West Virginia certified laboratory. Portable laboratories are not allowed, other than to choose which sample should be sent to an off-site certified laboratory.

- Under Title 46, Series 12, *Requirements Governing Groundwater Standards*, all metals—except chromium and Nitrate and Nitrite—must be dissolved or filtered samples. This filtering must be completed in the field. Chromium and Nitrate and Nitrite, under the same regulations, must be a total or unfiltered sample.

- Any TPH analytical test can be tailored specifically toward an exact contaminant, if a sample of that contaminant can be obtained. The TPH test method used at this time (February 2004) is EPA Test Method 8015-B (and not the old 418 test). TPH testing can be divided into GRO, DRO, and ORO carbon ranges. It should also be noted that—while Laboratory A’s method may separate TPH into all three ranges—Laboratory B’s DRO range may include the ORO range. It is therefore very important to communicate with the laboratory to determine what ranges their individual TPH tests include.

It should also be noted that TPH analysis is a somewhat imprecise test, and that the analyses will not repeat themselves. In addition, TPH analysis not only includes the contamination itself, but also the degradation products of that contamination. Some persons suggest not using TPH analyses because of this last factor, and that the individual component compounds of the hydrocarbons should instead be tested for; however, the hard fact remains that TPH testing will locate contamination that BTEX and PAH analyses will not find.

THE SITE INVESTIGATION REPORT:

Once any site investigation or groundwater sampling event is completed, a report documenting what was done should be sent to the Groundwater Program. Two copies of this report should be provided, so that a copy can be given to Environmental Enforcement. It is ***very*** important to note that all maps should contain a title, bar scale, north arrow, and date. The report should include the following:

- *A site location map:* This should include enough nearby area so that the site can be competently located. A portion of the relevant 7.5-minute (where one inch equals 2000 feet) USGS topographic map is preferred, and the latitude and longitude of the site should be included.

- *A site map:* This should be of a scale that adequately displays the site, and should show any structures, etc. that might be relevant to the investigation and remediation. It may be necessary to include more than one map, if the historical structures that have been removed are important.

- *A text description of the site:* This should be brief and include the relevant history of the site and its potential contamination.

- *A text description of the work completed:* This should also be as brief as possible, and should include a description of any excavation, soil boring, and/or geoprobe work, as well as any groundwater monitoring wells that have been installed within the reporting period. It should also include a brief description of how this work was performed, how the soil and groundwater samples were collected, and how the equipment was cleaned and disinfected between sampling.

- *Soil contamination maps:* these are isopath (contour) maps that show the concentrations of the soil contamination. It may be necessary to provide more than one map, if there is more than one contaminant, and if the contamiantion is found at more than one depth.

- *Top-of-groundwater maps:* these are isopath maps that show the surface (and flow direction) of the groundwater table. It may be necessary to provide more than one map if there is more than one groundwater zone at the site. It is ***very*** important that any groundwater map include a date of when the data was collected.

• *Groundwater contamination maps:* these are isopath maps that show the concentrations of the groundwater contamination. It may be necessary to provide more than one map if there is more than one contaminant.

• *Summary:* This section should include any relevant conclusions and recommendations.

• *Tables:* All soil and groundwater results can be included in as text, but they must also be included in tabular form. A letter abbreviation should not be used to report a concentration that is below the laboratory minimum detection limit (such as “ND”); rather, the method “<X” should be used, where “X” is the minimum detection limit, as this will allow the table user to ascertain that detection limit. In addition, the abbreviations “ppm” and “ppb” should not be used. Instead “mg/l,” “µg/l,” “mg/kg,” and “µg/kg” should be used, as this designates what matrix (solid or liquid) was tested. All data should be dated as to when that data was collected.

• *Groundwater elevations:* If groundwater monitoring wells exist or were installed at the site, then a table delineating their wellhead elevation, diameter, top-of-screen elevation (or depth), bottom-of-screen elevation, and bottom-of-well elevation is required. In addition, a table showing the all the recent and historical groundwater elevations (with dates) should also be included.

• *Geological, drillers, and well logs:* If a soil boring or groundwater monitoring well was installed during the reporting period, then the relevant geologist and well logs should be included. In addition, if groundwater samples were collected, then a physical description of this sample should be included in the report. It should be noted that a West Virginia Certified Monitoring Well Driller must be used for all groundwater monitoring work, including the drilling, completing, modifying, and abandonment of any well.

• *The laboratory analysis sheets:* The laboratory analysis sheets for any laboratory work completed during the reporting period should be included with the report. It should be noted that all laboratory analysis must be completed by a West Virginia Certified Laboratory.

• *The chain-of-custody forms:* The chain-of-custody forms for any samples transported to a laboratory during the reporting period should also be included.

SITE REMEDIATION:

If it becomes necessary to remediate the site, then there are several options that can be employed. These are:

- *Free product removal:* free product can be removed by several different methods: by manually bailing the product off the top of the groundwater; by using a Petrotrap device, which allows only the product to flow into a collecting chamber; by absorbent socks or pads placed in the groundwater monitoring well; or by using a pump to remove the layer. While the product is usually removed via vertical groundwater monitoring wells, it can also be collected through horizontally placed piping. The product can also be removed using a device that uses a motor to chase the groundwater table up and down within the well, or two pumps can be used—one to remove water and create a cone of depression in the groundwater table, and the other to remove the free product that has flowed into the depression. The removal of any free product, if that product is present, should be given the highest priority of any remediation program. The amount of product and its proper disposal must be thoroughly documented.

- *Pump and treat systems:* this is a system where the contaminated groundwater is removed from the subsurface using a large-diameter groundwater monitoring well (or wells). This recovered water is then treated, and disposed of in some manner—either to a surface stream or the facility water treatment system via a NPDES permit, or back into the subsurface via a UIC permit. This method may be employed to remove free product or dissolved-phase contamination. It is usually used in aquifers with relatively high permabilities or where there is just a small area of contamination. Vertical wells are usually used; however, horizontally placed piping can also be employed.

- *High vacuum systems:* These are systems similar to pump and treat systems; however, a high vacuum system pulls not only free product and dissolved-phase contamination, but it also removes vapor contamination from the soil. These systems can be used continuously or intermittently, such as once a month or once a quarter. And, because their primary method of remediation is via vaporization, these systems can be used to remove both hydrocarbon and solvent contamination. In addition, if any contaminated soil has been previously removed, then the vacuum system can be enhanced by the installation of an impervious synthetic liner in the bottom of the excavation (and before that excavation is filled in). While the vacuum is usually applied via vertical groundwater monitoring wells, it too can be used though horizontally placed piping.

A vacuum truck removing free product and dissolved-phase contamination from a groundwater monitoring well.

- *Bio-vent systems:* These systems produce a much lower vacuum than a high vacuum system, but are usually operated over a greater period of time. Bio-vent systems will remove dissolved- and absorbed-phase contamination, but their vacuums do not have the power to remove free product. In addition, the wells in use (and their vacuums) are often varied to increase the efficiencies of these systems. Bio-vent systems, because they are moving low volumes of air through the subsurface, work only with contaminants that require oxidization, such as hydrocarbons. These systems will not remediate contaminants that require reduction, such as chlorinated solvents.

- *Soil vent systems:* These are systems that passively vent the soils, and do not induce any kind of artificial vacuum. They usually employ some kind of device on the well head that allows oxygen and not nitrogen to flow into or out of the wells, and they will only work with contaminants that require oxidation to remediate.

- *Air sparge systems:* These are systems where air is pumped down into wells and allowed to filter up through the subsurface contamination. As with all forced-air systems, air sparging works best in a permeable subsurface, and it works best with contaminants that can be oxidized. However, because sparge systems not only oxidize the contamination, but also vaporize it, these systems will remediate a wide range of contaminants, including those that require a reducing bioremediation environment, such as chlorinated solvents. The big disadvantage with all forced-air remedial systems is that, while they readily remediate lighter-end hydrocarbons that vaporize easily, such as gasoline, they are far less effective on heavy-end hydrocarbons that have lower water solubilities and lower vapor pressures, such as diesel fuel and fuel oil. In addition, it is important that air sparge wells have competent surface seals. Otherwise, the system can "short circuit" and the air come back up around the well, instead of flowing out from the well and through the contaminant.

A biovent system with underground connecting piping.

- *Soil flushing systems:* These are systems where the contaminated soil is flushed repeatedly, either only with water or with water and some kind of a surfactant. Soil flushing systems are often used in conjunction with a pump-and-treat system, where the contaminated water is removed from the subsurface, treated, and then reinjected up-gradient of the contaminated area, so that the clean water will move more contamination down gradient and into the pumping wells.

- *Bioremediation:* This is a method where micro-organisms (bacteria) are allowed to attack the contamination. This method can be used *in situ* or in the soils that have been removed and a biopile constructed. Piping can be installed either in the *in situ* or removed soils, and this piping can be used to move air through the soils, thus enhancing bioremediation, and/or to add nutrients and liquids to the contaminated soil. It should be noted that most hydrocarbon soils will often remediate themselves, if given enough time and provided there is a continuous source of oxygen. The problem is that this self remediation usually only occurs around the edges of the contaminated area, where there is oxygen, and not in the central part of the area. Thus, providing oxygen and nutrients to the middle of the contamination can always enhance remediation. All removed soils should be kept under plastic and placed on bermed plastic, so that the soils do not contaminate either the stormwater or groundwater.

- *ORC:* Oxygen-releasing compounds can be used at hydrocarbon-contaminated sites to add an oxygen agent, such as hydrogen peroxide, to the subsurface. This will enhance both the natural degradation and bioremediation of the contaminant. The ORC product can either be added in a liquid form via a groundwater monitoring well or as a powder in an open excavation (that will soon be filled in). An UIC permit is required to “inject” this compound in any kind of well, and this permit must be renewed annually.

- *SRC:* Subsurface-releasing compounds can be used at solvent-contaminated sites to add a reducing agent, such as sulfur or manganese, to the subsurface. This will enhance both the natural degradation and bioremediation of the contaminant. The product can either be added in a liquid form via a groundwater monitoring well or as a powder in an open excavation. An UIC permit is required to “inject” any compound, and this permit must be renewal annually.

- *Phytroremediation:* This is the strategy of using plants, such as trees or grasses, to remove the subsurface contamination. For example, tree roots not only add oxygen to the subsurface, assisting with the remediation of a hydrocarbon, but the tree’s roots, stems, and leaves will move the contaminant from the ground and then transpire it into the atmosphere. In addition, phytroremediation has the added advantage of slowing both groundwater and contaminant flow, and keeping more of the contaminant on site.

- *MNA:* Monitored Natural Attenuation is the process of allowing the contamination to “remediate itself” without outside assistance. MNA is not a “do nothing” strategy; rather it is a process where the contamination is carefully monitored to insure that it is decreasing. A secondary plan should be kept in reserve, in case the MNA process does not work and more aggressive strategies are required.

- *Soil excavation:* If it can be employed, soil excavation is a extremely efficient method of removing contamination. Its main disadvantages are that the contamination must be near the surface, the soil volume must be relatively small, good access is required to the site, and the process is expensive. Its advantages are that it is quick, simple, and effective, and will remove heavy-end hydrocarbon contamination—these are compounds that are very difficult to remediate and which many *in situ* strategies simply cannot effectively attack. Once the contaminated soil has been removed, it can be treated on site and replaced in the excavation, stored in a bio-pile, or disposed of at a properly constructed landfill. The walls and bottom of the resulting excavation are sampled to insure that no contamination remains. In addition, because the open excavation becomes a collecting point for any liquid, substantial quantities of free product and contmainated groundwater can also be removed.

SOIL EXCAVATION CRITERIA:

If a company chooses to over excavate their on-site soil contamination (as if they were removing a leaking underground storage tank), then they should use the following criteria:

- All the soil contamination should be removed back to a concentration determined beforehand by the Groundwater Program.

- At least one soil sample should be collected from each side wall of the excavation, and at least one soil sample should be collected from the bottom. This will equal a minimum of five samples. If any of the walls of the excavation exceed 30 feet, then one soil sample should be collected for each 30 feet of side wall and each 900 square feet of bottom.

- All soil samples should be grab samples, and should be collected from those locations where the soil contamination appears the worst, using a PID (or FID), and sight and smell.

- All the soil samples should be analyzed for BTEX and TPH-GRO for a gasoline-contaminated site and for TPH-DRO and a suite of PAHs for a diesel-contaminated site. Only a select number of soil samples need be sampled for the suite of PAHs; however, this suite should include those five PAHs that are the most soluble in water: fluorene, phenanthrene, naphthalene, acenaphthene, and acenaphthylene. All TPH testing should be via EPA Method 8015-modified, and all samples should be analyzed at a West Virginia Certified Laboratory. In addition, it may be necessary to also test the soil for lead and MTBE.

- It may be necessary to allow the excavation to remain open while the laboratory

A soil excavation.

analyzes the collected soil samples. This will allow additional contaminated soils to be removed if the first set of samples are found to contain significant contamination.

• All the removed soil should be hauled to an appropriate and licenced facility. Accurate records should be kept of how much soil is removed and to what location it is taken.

• Accurate records should be kept of any liquids encountered in the excavation. All free product and contaminated water should be collected and disposed of at a proper facility, and accurate records should be kept of how much liquid (and what kind) is removed and to what location. It may also be wise to analyze any water encountered for the same parameters that were tested for in the soil. While the lead testing may include total lead, it must include dissolved lead, as this is required by Title 46, Series 12, *Requirements Governing Groundwater Standards*. All analytical work must be completed by a West Virginia Certified Laboratory.

• No foundation or like structures should be compromised during the excavation of the contaminated soils.

• Both the Groundwater Program and the local Environmental Enforcement office should be contacted approximately one week before work begins in the field, so that both have the option of being present while the field work is being completed.

- If the contaminated soils cannot be removed back to the agreed-upon concentrations, or if significant quantities of free product or contaminated groundwater is encountered, then additional soil remediation and/or a groundwater monitoring program with properly constructed and completed wells may be required.

THE END OF THE REMEDIATION PROCESS:

The Groundwater Program uses two basic methods to determine if the completed remediation process has been successful. These are:

- If the contaminated soils have been successfully removed back to the agreed-upon concentrations, and if no contaminated groundwater or free product is encountered, then the remediation is considered successful.

- If the soil contamination is extensive or cannot be removed back to an agreed-upon concentration, or if the site was found to contain significant quantities of free product or groundwater contamination, then a groundwater monitoring program will be established. These wells must be installed by a West Virginia Certified Monitoring Well Driller in accordance with Title 47, Series 59, *Monitoring Well Regulations*, and Title 47, Series 60, *Monitoring Well Design Standards*. The wells will be sampled regularly for the contaminants of concern, and the remediation will be considered successful if a downward trend leading to insignificant levels of contamination is established. This monitoring program may also include surface water sampling and spring sampling.

Once it has been determined that the site remediation has been successful, the Groundwater Program will provide the affected party with a No Further Action letter. This letter is a legal document that can be used, by the property owner, as documentation that the site no longer contains significant subsurface contamination.

If the site is an active facility, then a Groundwater Protection Plan will be required to insure that such contamination does not occur again. Mr. Rick Shaver, of the Groundwater Program, should be contacted to begin formulating such a plan. Mr. Shaver's phone number is 304-926-0499, extension 1052. His e-mail address is rshaver@wvdep.org.

CONTACT INFORMATION:

For more information regarding the Groundwater Program remediation policy, please contact:

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Harlan Spring, Berkeley County