# WHY I HATE HYDROGEOLOGY

**Keynote Address to GRA Fifth Annual Meeting 1996**

(Slightly Expurgated for Public Consumption)

*by Joseph H. Birman, President*
*Geothermal Surveys, Inc. (dba GSi/water)*

## INTRODUCTION

Thank you, Ladies and Gentlemen. I am especially honored to have been invited to give a keynote address to this highly respected organization. In return, by the time this talk is finished, I will probably have insulted everybody in this room. I will try to do this fairly, with no regard to religion, race, or technical persuasion. I consider myself an equal-opportunity offender.

I will start by insulting myself. I am a hypocrite, as I will explain to you later.

This conference is titled Multidisciplinary Solutions for California Ground Water Issues. In that context, I would like to identify that discipline that I consider to be the most important, the most powerful, and the most crucial for investigating ground water and providing solutions to California's ground water issues. Boy, have I got a discipline for you!

For many years, the discipline has been in operational limbo. The hydrogeological profession provides it little shrift, often treats it with disdain, and sometimes ignores it completely.

Yet, the discipline is fundamental to the proper use and integration of all the other disciplines that you will examine in this conference. When that discipline is properly used, it gets us ninety percent of what we need to know in understanding ground water and what controls it. And it does this at far less than the costs of the other disciplines those that get us a part of that last ten percent.

The discipline is : I'm not going to tell you just now. I would rather lead up to it by means of a little philosophy.

When I accepted your invitation, I thought I would describe a rather nice technique that would fit into the multidisciplinary theme of this conference - the use of temperatures to trace the movement of ground water. In the course of hydrogeological investigations near Burbank, this technique revealed something interesting about the ground water. And in turn, the ground water told us something interesting about the geology.

That's the point: the ground water told us something interesting about the geology: namely that the eastern part of the San Fernando Valley might be crossed by a northwest-trending extension of the Whittier Fault. If true, this could be a significant finding in the geology of the Southland.

And then I realized that in the course of this work I had sinned. How had I sinned? I had gone out and committed hydrogeology. I had used hydrology to learn about the geology.

To make matters worse, not only had I **committed** hydrogeology; I even got myself **certified** as a **hydrogeologist**. Therein lies the hypocrisy. I got myself certified as a hydrogeologist even though I am profoundly averse to this misfortunate, this misleading, this dangerous term.

Think about it. "HYDRO-GEOLOGY". In this term, geology is a noun. Hydro is only a modifier of that noun. This hybrid term implies that the objective is geology, and that we are using hydrology to get us to the geology.

This is dangerous. If we forget that geology is the means to achieving the hydrological objective, we can pay superficial attention to the geology and leap to premature and inadequate conclusions about the ground

water.

## THE CRUCIAL DISCIPLINE

So what IS that powerful, crucial discipline? It is NOT our company's thermal technique for tracing the movement of ground water and finding a new fault in the San Fernando Valley. That technique is nice, but it's not crucial.

The most powerful discipline available for solving the Groundwater Issues of California is used superficially if it is used at all. In these days, it is often despised among hydrogeological sophisticates who teach in or graduate from prestigious academic institutions. That's because the most important tools of this discipline are a pencil and a piece of paper. At a higher level of technical complexity, the tools are a hammer, a hand lens, a compass, and a shovel. Few hydrogeological sophisticates know or remember how to use these tools.

Ground water lives in the geology. Ground water is controlled by the geology. The powerful, crucial discipline for solving ground water problems consists of going out into the field and doing geology. Really doing geology. Doing real geology. Mapping. Describing. Interpreting. And based on abundant geological data, formulating and prioritizing multiple working hypotheses that relate to the ground water problems.

In the archives of Sacramento, I am a HYDROGEOLOGIST. They can think that if they wish, but I know better. What I am is a GEOLOGICAL HYDROLOGIST. I do geology - a lot of it - to learn about hydrology. Today, Sacramento and the University of Arizona notwithstanding, I emerge from the closet as a GEOHYDROLOGIST. I use this term with great pride. It was introduced many years ago by ground water professionals much wiser than I.

## MULTI-DISCIPLINARY APPROACH

The title of this conference brings to mind all sorts of new and wondrous things. We are here to look at new technologies, new arts, new states of old arts, wonderful new hardware, wonderful new software, breakthroughs in water quality analysis down to the trillionth and heading toward the quadrillionth. The journals are filled with elegant mathematical derivations that are so complex, so convoluted, and so involved that only a small intellectual elite can understand them. Or do they?

The journal Ground Water is still a rather useful publication because it has not yet reached the sophistication of Water Resources Research. Almost nobody reads Water Resources Research. Almost nobody wants to. Almost nobody in our profession can follow the glut of esoteric mathematical symbols, the profusion of terms that defy explanation, and graphs that are sometimes so complex as to be ludicrous. Water Resources Research will get you tenure in Academia or another government grant in a national lab. But it won't get you much water. Why not? Because it does not sufficiently recognize what the geology of this planet is really like.

The perplexed members of the tenure committee (I used to be one of them) can't understand the articles either. The articles are so incomprehensibly complex that the writer must really be smart. Gee, we'd better give this one tenure.

Pick up any issue at random, and you will find it filled with games. These are mind games purporting to explain how ground water works under different conditions of the setting. Few of these games are based on a real-world geological study. Most of these games are based on nothing but **conceptual**-model departures from the Theis Assumptions. Most of these game-players look more into the computer screen than into the ground.

And the data-logger, that idiot-savant, is more and more replacing the sentient, judgmental human observer in the field.

And that naked emperor, the Unified Soil Classification effectively conceals and prevents from any useful interpretation just what the drill is bringing up out of the ground; that which the ground water has to travel

through.

Darcy's Law and the Theis Nonequilibrium Equation are the best tools we have going for us in trying to quantify and predict the flow of ground water. Scratch Water Resources Research, and you will keep on finding Theis. Commendably, what those tenure-and-grant seekers are trying to do is to make Theis work in the complexities of the real world.

But they can only approximate. And to the extent that their models are not based on geological reality, their supposed solutions to water problems are not very useful (how many times have **you** been able to use them)?

Because as you know, the Theis Nonequilibrium Equation is based on assumptions. Twelve of them. You know what they are: such things as horizontal, infinite, homogeneous and isotropic, fully penetrating, 100 per cent efficiency in a pumping well of infinitesimal radius, and on and on.

And almost none of these assumptions is correct in the real world. Each of these assumptions departs from reality in varying degrees depending on the geology of a particular setting.

With twelve assumptions, and with the geology of each site varying in different amounts, the number of permutations involving the twelve assumptions is enormous. Enough to keep the tenure-and-grant-seekers playing mind games until the end of the next Millennium.

So our most valuable tools for quantifying and predicting the flow of ground water are not easy to use. They must be applied with great skill and with great insight. Their value - success or failure with ground water issues - will depend directly on how well the geological details at each site are known.

And that, my geological colleagues, is where you come in.

Because if the Theis Assumptions were correct; if aquifers were isotropic and homogeneous, no hydrogeologists or geohydrologists would ever be needed. Anybody could put three observations wells around a pumping well, install some dataloggers and a computer will answer all the questions you have been struggling to answer in this real, horribly complex world.

Your success with ground water depends entirely on finding out which of the Theis Assumptions are reasonable; and how their variations are distributed laterally and vertically in space and in time. And which of the Theis Assumptions are not reasonable. This means nothing more (**and nothing less**) than understanding the geology in which our water lives: the geology of its source and the geology of the three dimensional space in which it moves.

There are only two types of professionals that think an aquifer is homogeneous and isotropic: water witches and civil engineers.

Geologists know better. Geologists know that if you want to prevent technical and financial disaster with a lot of unnecessary drilling; if you want to control the ground water; if you want to take more water out of the ground; if you want to put more water into the ground; if you want to understand the interchange between surface water and ground water; if you want to protect the environment; you had better know as much about the geology as you can **before** you send a drill bit into the ground.

And especially before you construct a computer model. What about THOSE assumptions?

It is the geology that controls the ground water, and I have never known an excellent ground water hydrogeologist who was not at the same time an excellent geologist.

Tomorrow, a much better Keynote Speaker will tell you about water on Europa. A fascinating, stupendous concept.

But keep in mind, you geologists, that it is probably easier to see water halfway across the Solar System than three hundred feet beneath where you now sit. The intervening space between here and the water on Europa is transparent. Beneath this room, the space that intervenes between you and the ground water is filled with what to the non-geologist is chaos.

And only you geologists can perceive order and extract comprehension out of that chaos. The mathematicians can't do it. The physicists and chemists can't do it. The biologists can't do it. The engineers can't do it. The lawyers can't do it. Only you can do it.

Do not abdicate to the Unified Soil Classification and to the exclusive use of the data-logger your responsibility to really know the geology. Your responsibility is awesome. Because what you are struggling to make available to the life that inhabits this planet is the gift of its very survival.

To the geologists in this audience, I say, listen to the presentations in this fine conference. Keep in mind that all the wonderful new disciplines that you will hear about can be effective only if they are applied into a context of geological understanding. Those disciplines can **enhance**, they can **refine**, but they can never **replace** the 90 percent of geological understanding that only you can provide.

HYDROGEOLOGIST - GEOHYDROLOGIST, call yourself what you will. But always remember: Geology is the Discipline that has to come first.

Ladies and Gentlemen, I thank you very much.

*Joseph H. Birman is Professor Emeritus, Occidental College and is President of Geothermal Surveys, Inc. (dba Gsi/water). Gsi/water, a Los Angeles based geological-geophysical company, in its 35th year of business specializing in: Ground water resources exploration and assessment; well location and design; aquifer and well performance testing; hydrologic modeling; dam leakage detection and monitoring; environmental hydrology and monitoring; geothermal resources exploration; landfill monitoring; and video-based fracture analysis.*

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# Branch Activities

**San Francisco Branch**
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*by Jim Ulrick, Branch Secretary*

For our September meeting, we were fortunate to have Dr. Jon Marshack from the Central Valley Regional Water Quality Control Board. Dr. Marshack gave a perspective on the framework for water quality regulations in California.

Water quality regulation in California began with the Porter-Cologne Water Quality Control Act in 1969. This Act created the nine Regional Water Quality Control Boards and the State Water Resources Control Board. State and Regional *Water Quality Control Plans* (Basin Plans) define *beneficial uses* of surface and ground waters for each region of the state. Under the Porter-Cologne Act, the discharge of waste is a privilege, subject to specific permit conditions, not a right. Thus, the Regional Boards issue *Waste Discharge Requirements* or *Orders* that specify the permit conditions for the discharge of waste.

In addition to beneficial uses defined in Basin Plans, the state also defines *Water Quality Objectives*, which consist of narrative objectives and numerical limits for the reasonable protection of water quality.

Mr. Marshack noted that risk assessment does not necessarily protect the quality of a water resource. Risk assessment is aimed at protecting humans or organisms at the point of use. Where there may be multiple sources of water quality degradation, the state does not allow a single source to degrade a water resource to the threshold of its beneficial use because that would not allow for any additional degradation. The concept of *reasonableness* applied to the protection of beneficial uses assesses the incremental cost for incremental degrees of protection.

An understanding of water quality regulation can be an asset in compliance and site remediation.

Additional information on water quality regulations in California can be found in the Basin Plans prepared by each of the nine Regional Boards and in *A Compilation of Water Quality Goals*, July 1995 (updated April 1996), available from the Central Valley Regional Board.

Our October meeting was held at the San Mateo County Office Building in Redwood City. This was a combined workshop and dinner meeting on "Developing Fingerprinting Information for Petroleum Hydrocarbon Identification" presented by Dr. James Bruya, expert forensic chemist.

Dr. Bruya discussed the petroleum refining process and its variations: among manufacturers, among refineries, in distribution, and over time, emphasizing the complexity and variability of commercial petroleum products, such as gasoline and diesel fuel. Chemical markers, preservatives, performance improvement additives, dyes, tracers, and changes in chemical composition due to aging, partitioning with water, evaporation, and biodegradation were also illustrated. The advantages, shortcomings, and interpretation of the numerous volatile and semi-volatile analytical methods useful in hydrocarbon fingerprinting were discussed and illustrated with case histories. The importance of analytical quality control and quality assurance was emphasized, due to the subtlety of the interpretation of analytical results. Petroleum hydrocarbon identification is an exacting and challenging task. Dr. Bruya's enthusiastic presentation gave us a sufficient introduction to understand the range of techniques that are available.

**Southern California Branch**
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*by Jim Carter, Branch President*

The Southern California Branch was pleased to host the Fifth Annual Meeting of GRA on October 10th and 11th. The event was a big success! It was held at the Wyndham Garden Hotel in Costa Mesa and was attended by over 125 groundwater and environmental professionals. To paraphrase the President's welcome, the theme of the meeting, titled "Multi-Disciplinary Solutions to California Groundwater Issues," was an outgrowth of last year's annual meeting. At that meeting it was very obvious that a multitude of disciplines are needed to address California groundwater issues and that each discipline could not work in a vacuum. With that in mind, we developed the theme of this year's meeting to examine the multi-disciplinary solutions to California groundwater issues.

Special concurrent symposia addressed groundwater resources and environmental contamination issues, with the topics relevant to the meeting's theme. It was quite amazing how the various presentations all came together, with ideas from one talk building on the next!

The Groundwater Resources sessions were presented on Thursday and Friday, and included the following topics: Implications of the Safe Drinking Water Act on the Groundwater Industry; Superfund Issues; Reclaimed Water Issues; Key Issues for Groundwater Management Plan Implementation; Surface Water and Groundwater Interface Issues...The Fine Line; and a panel discussion on Groundwater Management: What is the Best Way?

The Environmental sessions were presented on Thursday, with Friday being devoted to an all day short course. The short course was titled "ASTM Risk-Based Corrective Action (RBCA) Framework Training Session," and the instructor was Dr. E. Essi Esmaili. The topics presented in Thursday's sessions included: Re-Examining Groundwater Cleanup and Performance Goals; In-Situ Remediation Techniques; and a panel discussion on The Changing Landscape of Groundwater Protection and Cleanup Policy.

The Southern California Branch would like to thank all those who participated and helped to make the meeting a success. First of all, Susan Garcia (Foster Wheeler Environmental) made a tremendous effort to organize and direct the meeting. Supporting Susan were Jim Carter (SPL Laboratories), Mark Cutler (Foster Wheeler Environmental), Lou Reimer (Consulting Geologist), Carl Hauge (California Department of Water Resources), and Vicki Kretsinger (Luhdorff and Scalmanini). Thanks also to those who helped run the meeting, including: Brian Lewis (Cal DTSC); Tony Ward, Carmen Guzman and Sean Coles (Geraghty & Miller); and Carol Reimer. And of course, we would like to thank our speakers and vendors for their time and effort in making the meeting interesting and thought provoking.

**Sacramento Branch News**

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*by Tom Mohr, Branch President*

The September Sacramento Branch Meeting featured a presentation by Gerald Church of Transglobal Environmental Geochemistry on a Natural Attenuation Protocol for Intrinsic Bioremediation of Hydrocarbons in Groundwater. Mr. Church used case studies to describe the natural attenuation approach, in which contaminant concentration data and geochemical indicators are used to demonstrate that a plume is stable or shrinking, and that clear evidence exists to ascribe decreasing concentrations to biodegradation. The natural attenuation approach requires sufficiently detailed characterization of contaminant distribution and system biogeochemistry to yield estimates of the rates of natural attenuation and assimilative capacity for each contaminant. The typical hydrocarbon plume will have an anaerobic core and an aerobic fringe. Oxygen is replenished to the plume fringes by infiltration from the vadose zone.

Mr. Church reported that the draft ASTM guidelines on Remediation by Natural Attenuation (RNA) views this technique as one best used in combination with other approaches. He estimates that the cost to conduct site characterization for RNA may be twice the cost of traditional site characterization for a small site, but larger sites would cost less than double.

Among techniques of documenting that biodegradation is the predominant factor in reduction of contaminant mass, Mr. Church noted that stable isotope ratios of sulfur and nitrate have been applied to better understand background levels of these compounds. The bacterial reduction of substrate results in the isotopic enrichment of the S34/S32 and the N15/N14 ratios. Stripping and analysis of dissolved gases is critical to understand biodegration rates of RNA. TEG has successfully used peristaltic pumps to drive a gas stripping device for on site analysis of dissolved hydrogen, based on

oil patch technologies used to characterize ocean micro seeps. Mr. Church shared his view that application of RNA to DNAPL plumes is limited by the difficulty in characterizing contaminant distribution and aquifer heterogeneity.

He emphasized the importance of detailed subsurface characterization, and recommended the Strataprobe in combination with a mobile laboratory as the direct push technology of choice. The Strataprobe, which Church refers to as a "Geoprobe on steroids," is capable of advancing to depths of 100 feet, collecting continuous core, soil vapor samples, grab groundwater samples, and, most recently, gamma logging for lithology. Field testing of this natural gamma logging tool with OD 3/4" is in progress in Denver. For more information, contact Gerald Church of TEG at 818-848-6374.

The Annual Winterfest Meeting will be held on December 12, 6 PM, at the Royal Hong King Lum Restaurant, Sacramento. Professor Jeffrey F. Mount, University of California, Davis, will give a presentation titled, "California Rivers and Streams: The Conflict Between Fluvial Process and Land Use." Dr. Mount's presentation will feature an overview of river hydraulics, processes that shape rivers, and the interplay of climate and tectonics shaping river profiles in different regions of the state. The primary emphasis of this presentation will be on early efforts at flood control, the impact of hydraulic mining, gravel mining, logging, grazing, and agriculture, the concept of flood frequency and recurrence, effects of urban settlement, and the geomorphic response to dams. Dr. Mount's talk will be illustrated with a rich collection of slides. Contact Tom Mohr (916) 757-5575 for more information or if your firm would like to donate a gift as a door prize.

January 16th, 1997, will feature a talk on "New Uses for Old Chemistry: Groundwater Remediation Using Metallic Iron." Dr. Cindy Schreier, Ph. D. from SECOR will give the presentation. Contact Tom Mohr (916) 757-5575 for more information.

**Central Coast Branch**
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*By Deanna Cummings, Branch Secretary*

The Central Coast Branch held its September meeting at the Barefoot Bistro in Ventura. Geoffrey Bates, former Branch Vice President and Michael Bodart, General Pump Company, gave a talk titled "Evaluating Wells for Rehabilitation." This informative talk included the basics of well and pump record keeping, trouble shooting, and well rehabilitation. The speakers stressed the importance of well and pump daily inspection, and record keeping to show trends in well performance overtime. Also discussed were specific problems with their potential corrective measures. The problems covered included decrease in well yield, sand pumping, and structural collapse.

The November meeting was held in Santa Barbara. A power failure necessitated a change in restaurants after all the members arrived, but thankfully, Keeper's Lighthouse provided facilities for us at the last minute. Chris Conway, a graduate researcher at the Desert Research Institute (DRI), University of Nevada at Reno, discussed his research. His talk, entitled "Hydrogeologic Studies for Dust Mitigation at Owens Dry Lake," included the various components of the basin-wide water balance being prepared by DRI. Dust storms from Owens Dry Lake account for the single largest source of anthropogenic air pollution in North America. Groundwater from the Owens Dry Lake Basin is being considered for dust mitigation. Mr. Conway discussed his specific research, ephemeral stream flow and its groundwater recharge, as well as other components of the DRI research currently being conducted. Our thanks go to American Analytics for sponsoring the November meeting.

We are holding a joint Holiday meeting with the Coast Geologic Society Tuesday, December 17, 1996. It is Spouse/Guest night, and Ernest Weber of Cal State Fullerton will speak. His talk is entitled "Colorado River--River of Controversy". We hope to see you there!

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*Chemist's Corner*

# Is the WET Dead?

*by Bart Simmons*

This is the second in a series of columns on endangered test methods. Last time we discussed the fate of the test for Total Petroleum Hydrocarbons (TPH). Now we turn our attention to a controversial proposal to eliminate the use of the Waste Extraction Test (WET) for hazardous waste identification in California.

The WET was originally developed as part of guidance called the California Assessment Manual (CAM) - some labs still refer to the regulated elements as the "CAM Metals." The test was originally a series of four sequential extractions over a period of 30 days, in order to simulate what might leach from a waste if disposed in a municipal landfill. In response to objections over the sequential extractions, the test was shortened to a single 48-hour extraction, using a 0.2 M citrate buffer at pH 5.0. At the time the WET was adopted into regulations, the U.S. EPA had already adopted the Extraction Procedure (EP), the predecessor to the Toxicity Characteristic Leaching Procedure (TCLP), which is currently used in RCRA federal hazardous waste criteria.

The principal difference between the WET and the TCLP is the use of citrate in the WET vs. acetate in the TCLP. Citrate is known to chelate several of the regulated elements; acetate generally forms weaker complexes with regulated elements. As a result, the WET is generally more aggressive than the TCLP in extracting elements from wastes.

The California Department of Toxic Substances Control (DTSC) is currently conducting a Regulatory Structure Update (RSU) of hazardous waste regulations. As part of the RSU, DTSC is proposing changes to the definition of a hazardous waste. The Department had proposed elimination of the WET, but the proposal received challenges from some members of the RSU External Advisory Group, which represents a variety of interested parties. DTSC's Hazardous Materials Lab then conducted a study of the extraction of elements, comparing the extraction using the WET, the TCLP, and extraction with actual leachate from municipal solid waste (MSW) landfills in California. One notable result of the study was that the MSW leachates generally had low total organic carbon (TOC); most leachates had TOC less than 1,000 mg/L. The pH of the leachates ranged from 6.2 to 9.0, higher than the pH 5 used in the WET and TCLP. The relatively low TOC and high pH appears to explain why the leachates generally extracted less than either the WET or TCLP. The major conclusion of this study was that the TCLP generally better simulated extraction with MSW leachate than did the WET. One interesting finding was that a few MSW leachates extracted more arsenic than the TCLP, likely because arsenic is generally more soluble in the higher pH of the MSW leachates.

Based on the review of literature and the results of the RSU study, DTSC has begun a Phase 2 study to gather data on elements which were not included in Phase 1, and to do a longer term extraction, up to ten days, to simulate the extraction over a longer time period. Meanwhile, DTSC has proposed to use the TCLP in lieu of the WET and to use the results of the RSU Extraction Project to adjust the regulatory limits, if necessary, to compensate for any deficiencies found in the TCLP.

The elimination of the WET could result in the reclassification of a large volume of waste which is now regulated as non-RCRA hazardous waste. How this waste would be regulated will depend on the overall changes from the RSU process. The current schedule for completion of the draft regulations is June 1997. Until regulations are revised, the WET is very much alive, but its life expectancy may be short.

*Bart Simmons, Ph. D., is the Acting Chief, Hazardous Material Laboratory, Department of Toxic Substances Control, Berkeley, CA.*

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# The Containment Zone Policy Update

*by Tim Parker*

On October 2, 1996 the State Water Resources Control Board (SWRCB) voted unanimously to approve the "Containment Zone Policy" Proposed Amendment to Resolution No. 92-49, Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304 (Non-Degradation Policy). The Amendment provides conditions under which a Regional Water Quality Control Board (RWQCB) may establish containment zones (specific portions of groundwater bearing units where water quality goals cannot be reasonably achieved). The Containment Zone Policy is considered necessary to address existing SWRCB policies and procedures regarding groundwater cleanup levels that generally require cleanup to the highest level reasonably attainable where, at a minimum, water quality objectives (as specified in the RWQCB Basin Plans) must be met. The vote establishes a process to develop a statewide consistent policy on this issue that has been ongoing for nearly two years and has included two public hearings, a SWRCB workshop, and three previous draft amendments. SWRCB considers the new policy as a beginning: a dynamic document that will change with time. The Containment Zone Policy has been issued to the State Administrative Law Office for review. Typically a 30-day review process, the SWRCB hopes to have the approved Containment Zone Policy Amendment in place by the beginning of next year. Once the policy is in place, it will be up to the various RWQCBs to implement the new policy. This may require development of containment zone policy procedures and guidelines at the RWQCB level. It is interesting to note that several of the RWQCBs voiced the opinion that the policy is too restrictive, while other RWQCBs indicated the policy was not restrictive enough. While the existing Non-Degradation Policy already provides for restoration of water quality to "best water quality which is reasonable" in consideration of, among other things, water demand and economics, the new policy provides a more detailed mechanism for the regulators to follow when the technical argument is made that restoration of groundwater is technically and/or economically unfeasible. It seems like this a step in the right direction to streamline the groundwater cleanup process, cleanup goal negotiations, and provide some rationalization to groundwater restoration objectives. The question now is how are the RWQCBs going to implement the new policy, and when?

*Tim Parker, CEG, CH, is a Project Manager for Law Engineering and Environmental Services in Sacramento.*

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# NEW GRA HOME PAGE ADDRESS

*by Brian Lewis*

How many of you remember our home page address? In an attempt to make it more user friendly, we have adopted the domain name "grac.org." You can visit our home page at http://www.grac.org. We had hoped for "gra.org," but Georgia Research Alliance had already laid claim to that domain name.

We've also established six mail boxes to help you communicate with GRA at both the branch and state level. Four branches have mail boxes: sac.branch@grac.org,sf.branch@grac.org, socal.branch@grac.org, and cc.branch@grac.org (this last address may not be obvious, but it is for the central coast). We are hoping that the e-mail addresses will help with communication between members, branches, and the state organization.

At the state level, there are two e-mail addresses: admin@grac.org and editor@grac.org. The admin address is for administrative issues, such as new memberships, change of address, etc. The editor address is for our new *HYDROVISIONS* editor, Floyd Flood. Contributors to our newsletter can e-mail articles directly to the editor. Members can write "Letters to the Editor" as well as make comments regarding the newsletter using this address.

Our home page is also being updated. If you have suggestions on what you would like to see on the home page or would like to help design the page, send your comments and suggestions to editor@grac.org. If while browsing you the find a home page that should be linked to GRA's, let us know. Also, let us know of cool home pages that you like and why you like them. We may be able to mimic and incorporate some of the coolness into "grac.org,". Considering what I have seen in the last couple of weeks while browsing, the possibilities are endless.

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# The Groundwater Guardian Program:
# AN OVERVIEW

*by Harrison Phipps*

During the past three years, Groundwater Guardian community teams have organized to protect one of the world's most important, yet least appreciated resources, our groundwater. What these diverse groups of citizens have shown is that local people are in the best position to understand groundwater issues and respond appropriately and effectively to the challenge of protecting groundwater in the long-term.

Groundwater Guardian is designed to showcase these efforts, and connect people and communities through common concerns and experiences. From comprehensive wellhead protection programs, in large urban settings and corporate stewardship projects at manufacturing sites to citizen-led conservation and education programs, Groundwater Guardian projects focus on addressing local needs with local resources.

The Groundwater Guardian program rests on the principles that process is important, that every community using or benefiting from groundwater can, and should participate, and that it is a program led and shaped exclusively by participating communities.

Groundwater Guardian is a program which supports, recognizes, and connects communities protecting groundwater. It is designed to empower local citizens and communities to take voluntary steps toward protecting their groundwater resources. Groundwater Guardian can be a catalyst for groundwater protection programs such as local wellhead protection or source water protection programs. Groundwater Guardian is not a regulatory program; rather it relies on voluntary steps developed at the community level.

Groundwater Guardian is a program of the Groundwater Foundation. The Foundation is a non-profit, educational organization that informs and motivates people to care about and for groundwater. The program is made possible through grants from the W.K. Kellogg Foundation, the USGS, and the Office of Groundwater and Drinking Water at the U.S. EPA.

The above information was taken from "*A Community Guide to Groundwater Guardian*," 1996, by The Groundwater Foundation, PO Box 22558, Lincoln, Nebraska 68542-2558. For a copy of the Guide, more information about the program, or a list of Groundwater Guardian communities in California and across the nation, please write this address or call 1-800-858-4844.

*Harrison Phipps is the Executive Coordinator of the Water Resources Association of Yolo County (WRA). The WRA is a GRA member and received the Groundwater Guardian designation in 1994 and 1995 and is scheduled to receive the 1996 designation at the Groundwater Guardian National conference in Chicago in November, 1996.*

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# What is the Ground Water Disinfection Rule?

*By Bruce Macler, U.S. EPA, Region 9, San Fransico*

Under the Safe Drinking Water Act (SDWA), EPA is required to establish disinfection requirements for groundwater systems. A system in this case includes the source, well, treatment hardware and distribution lines. The existing Total Coliform Rule (TCR) mandates monitoring for fecal contamination in public water supplies, but does not explicitly require correction of violations or other identified problems. Additionally, it only acts "after the fact," since by the time TCR monitoring results have revealed contamination, people have already consumed the contaminated water. Congress asked EPA to ensure additional protection to the public to prevent such situations. Currently, many states have some groundwater system protection and/or disinfection regulations already in place, although the specific requirements vary substantially. The GWDR will provide the national guidance and requirements to correct problems and provide adequate protection.

## Why the Public Health Concern?

There are legitimate concerns for public health from microbial contamination of groundwater systems. Microorganisms and other evidence of fecal contamination have been detected in a large number of wells tested, even those wells that had been previously judged not vulnerable to such contamination. The scientific community believes that microbial contamination of groundwater is real and widespread. Public health impacts from this contamination while not well quantified, appear to be large. Disease outbreaks have occurred in many groundwater systems. Risk estimates suggest several million illnesses each year. Additional research is underway to better characterize the nature and magnitude of the public health problem.

## Current Thinking on Regulatory Elements

The working public health goal for the GWDR is to protect consumers from fecal contamination in their drinking water. To achieve this goal, the final regulation should ensure adequate protection of sources, wells and distribution systems from fecal contamination and provide treatment if contamination occurs. In addition, it must be feasible to implement and enforce. Options so far actively being considered center around a general requirement for a periodic sanitary survey to include wells and treatment, distribution, operations and management, and monitoring and assessment. Correction of fecal contamination or system defects would be required, which could include installation of treatment. Maintenance of a distribution system disinfectant residual (for systems with distribution) has wide support. A groundwater vulnerability assessment may be required. Highly vulnerable sources would have additional source water monitoring requirements. Monitoring requirements may focus on E.coli and coliphage as indicators of fecal contamination. Operator training or certification will likely be required.

## How Might Small Community Systems be Affected?

Groundwater-based public water supply systems are substantially different from surface water systems. Also, groundwater systems have very different circumstances with respect to each other and to the likely elements of this rule. Compared to larger groundwater systems, the small community systems (serving fewer than 1000 people) have fewer resources and less routine oversight. Small non-community systems (schools, restaurants, etc) typically have even more limited resources and infrastructure. Most have no distribution system. The majority do not disinfect or treat their water at all. Operators are generally not certified. These small systems have the majority of microbial violations, mostly from source or wellhead contamination. They are not well represented in the drinking water community. Because of their resources and limited current involvement with drinking water regulations, the GWDR would likely have the most noticeable impact on these systems. New SDWA amendments direct EPA to specifically consider the feasibility of regulatory requirements for small systems.

## Current Workgroup Activities

There has been wide and open participation in the regulatory discussions, including representatives from states, utilities, EPA, other agencies and interest groups. Over the last two years, broad issues of public health problems and goals, existing state protection approaches, vulnerability assessment methods and general treatment possibilities have been considered. As the workgroup discussions have developed, several topic areas have been identified for detailed study. Information-gathering groups are now examining the public health and microbiological monitoring issues, existing state and federal regulations and approaches, criteria for sanitary surveys, possible requirements for operations and maintenance, and appropriate treatment technologies. It is expected that these groups will bring forward their recommendations during 1996. EPA is anticipating a proposed GWDR by mid-1998.

## How Can You Get Involved?

The GWDR discussions are open to all. Interested parties are encouraged to participate, especially members from small communities. If you are interested or want more information on this rule, contact Bruce Macler, GWDR Regulation Manager, at 415 744-1884 or macler.bruce@epamail.epa.gov.

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# CALL FOR NOMINATIONS

The GRA Board of Directors is requesting nominations for GRA Executive Officers for the coming year. Officers are elected by the Board for one year terms of office. If you know of someone who would serve GRA in the coming year, please submit a written nomination listing the person's name and the office of nomination. Please submit your nomination to one of the GRA Directors. Directors are listed in *HYDROVISONS* and in your Membership Directory. You may also mail your nominations to: GRA, Attention Nominating Committee, P.O. Box 1446, Sacramento, CA 96812. The nominating committee is comprised of Tim Parker, Paul Dorey, and Susan Garcia. All nominations should be received by January 10, 1997. The election of the Executive Officers will take place at the January 20, 1997, meeting of the Board of Directors. The duties of each Executive Officers are listed below as outlined in our Bylaws. The Executive Officers are expected to attend the board meeting. The 1997 schedule for board meetings is listed on the back of *HYDROVISONS.*

## DUTIES OF PRESIDENT

The President shall be the chief executive officer of the corporation and shall, subject to the control of the Board of Directors, supervise and control the affairs of the corporation and the activities of the officers. He or she shall perform all duties incident to his or her office and such other duties as may be required by law, by the Articles of Incorporation of this corporation, or by the GRA Bylaws, or which may be prescribed from time to time by the Board of Directors. Unless another person is specifically appointed as Chairperson of the Board of Directors, he or she shall preside at all meetings of the Board of Directors. If applicable, the President shall preside at all meetings of the members. Except as otherwise expressly provided by law, by the Articles of Incorporation, or by the GRA Bylaws, he or she shall, in the name of the corporation, execute such deeds, mortgages, bonds, contracts, checks, or other instruments which may from time to time be authorized by the Board of Directors.

## DUTIES OF VICE PRESIDENT

In the absence of the President, or in the event of his or her inability or refusal to act, the Vice President shall perform all the duties of the President, and when so acting shall have all the powers of, and be subject to all the restrictions on, the President. The Vice President shall have other powers and perform such other duties as may be prescribed by law, by the Articles of Incorporation, or by the GRA Bylaws, or as may be prescribed by the Board of Directors.

## DUTIES OF SECRETARY

The Secretary shall:

Certify and keep at the principal office of the corporation the original, or a copy of the GRA Bylaws as amended or otherwise altered to date.

Keep at the principal office of the corporation or at such other place as the board may determine, a book of minutes of all meetings of the directors, and, if applicable, meetings of committees of directors and of members, recording therein the time and place of holding, whether regular or special, how called, how notice thereof was given, the names of those present of represented at the meeting, and the proceedings thereof.

See that all notices are duly given in accordance with the provisions of the GRA Bylaws or as required by law.

Be custodian of the records and of the seal of the corporation, if applicable, and see that the seal is affixed to all duly executed documents, the execution of which on behalf of the corporation under its seal is authorized by law or the GRA Bylaws.

Keep at the principal office of the corporation a membership book containing the name and address of each and any members, and, in the case where any membership has been terminated, he or she shall record such fact in the membership book together with the date on which such membership ceased.

Exhibit at all reasonable times to any director of the corporation, or to his or her agent or attorney, on request therefor, the GRA Bylaws, the membership book, and the minutes of the proceedings of the directors of the corporation.

In general, perform all duties incident to the office of Secretary and such other duties as may be required by law, by the Articles of Incorporation of this corporation, or by the GRA Bylaws, or which may be assigned to him or her from time to time by the Board of Directors.

**DUTIES OF TREASURER**

Subject to the provisions of the GRA Bylaws relating to the "Execution of Instruments, Deposits and Funds," the Treasurer shall:

Have charge and custody of, and be responsible for, all funds and securities of the corporation, and deposit all such funds in the name of the corporation is such banks, trust companies, or other depositories as shall be selected by the Board of Directors.

Receive, and give receipt for, monies due and payable to the corporation from any source whatsoever.

Disburse, or cause to be disbursed, the funds of the corporation as may be directed by the Board of Directors, taking proper vouchers for such disbursements.

Keep and maintain adequate and correct accounts of the corporation's properties and business transactions, including accounts of its assets, liabilities, receipts, disbursements, gains and losses.

Exhibit at all reasonable times the books of account and financial records to any director of the corporation, or to his or her agent or attorney, on request therefor.

Render to the President and directors, whenever requested, an account of any or all of his or her transactions as Treasurer and of the financial condition of the corporation.

Prepare, or cause to be prepared, and certify, or cause to be certified, the financial statements to be included in any required reports.

In general, perform all duties incident to the office of Treasurer and such other duties as may be required by law, by the Articles of Incorporation of the corporation, or by the GRA Bylaws, or which may be assigned to him or her from time to time by the Board of Directors.

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# PRESIDENT'S MESSAGE

*by Susan Garcia*

Stop, don't blink, 1996 is almost over. This fast-paced, action-packed year brought in our fifth year of existence. I am happy to say it has been a very successful year, albeit, not without growing pains. A brief overview of the year follows.

### *State Officers*

We started the year with three new state officers: Kent Parrish (Vice President), David Von Aspern (Secretary), and myself (President). This year was different, because unlike previous years, only one officer (Steve Goldberg, Treasurer) is also a Director. Through time, we developed a working arrangement to address this change. As a result of our efforts, we are considering revisions to our Bylaws which will further define the responsibilities and voting rights of State and Branch Officers (our Jan/Feb 1997 Hydrovisions will discuss this in more detail).

### *Executive Director Position*

We also started the year with Jim Graham as Executive Director, a position created in 1995 to help advance our organization. Increasing demands from Jim's new legal practice resulted in Jim consolidating his priorities and resigning his position as GRA Executive Director. We wish Jim the best in his legal practice. The void created by Jim's absence has resulted in some of our membership experiencing difficulties in obtaining responses to their inquiries and in receiving notices and announcements. We apologize for these inconveniences. In the interim, many of GRA's administrative duties will be assumed by the following individuals:

1. Membership inquiries should be directed to Paula Noble at (916) 661- 0109 (voice) or (916) 661-6806 (fax). Tom Mohr and Maria Kamau have been updating our membership database. These tasks will be assumed by Paula. Membership questions can be directed via e-mail to **admin@grac.org**.

2. *HYDROVISIONS* production has been assumed by our new editor, Floyd Flood, with assistance from Brian Lewis and Anthony Saracino. David Abbott has been helping to remind contributors of the deadlines.

3. Our Web Page updates are being coordinated by Brian Lewis, Tim Parker and other Web Page Committee members.

We thank these individuals for their assistance. We are currently re-evaluating our need for an Executive Director position and will announce our findings in the January 1997 Hydrovisions. In the meantime, please make sure you direct all written correspondence to: GRA, P.O. Box 1446, Sacramento, CA 95812; mail should no longer be sent to Jim Graham's office.

### *Accomplishments for 1996*

I am pleased to say as a five-year-old organization, we have accomplished many things this past year; including:

1. Increased our membership from about 600 last year to almost 700 this year.

2. Produced a successful Fifth Annual Meeting, held for the first time in Southern California (more about this meeting later).

3. Co-sponsored two events...a workshop on "Ground Water Management: Who's Carrying the Ball?" at the Association of California Water Agencies' Spring Conference and a "Bay Delta Institutional Issues Assembly," coordinated by the California Assembly Process, POWER, and the Water Education

Foundation.

4. Developed a Web Page so that information could readily be disseminated to our membership. Our new URL is http://www.grac.org. Special thanks to Brian Lewis, Tim Parker and other Web Page Committee members, for developing the page.

5. Produced four editions of *HYDROVISIONS*, containing technically informative articles contributed by a variety of technical experts throughout the state.

6. Planned an excellent seminar on "Rapid Site Characterization: Process, Tools and Data Quality," where Dr. John Cherry from the University of Waterloo was the keynote speaker.

### *GRA's Fifth Annual Meeting*

GRA's Fifth Annual Meeting on "Multi-Disciplinary Solutions to California Groundwater Issues" was a resounding success (in my humble, biased opinion). The meeting accomplished our objectives of providing a forum for technical exchange and for discussing potential solutions to groundwater issues that face us in the groundwater industry. Informative presentations were given by the various speakers on talks, including arsenic and the Safe Drinking Water Act; Wellhead Protection; Legal Implications Associated with Surface Water and Groundwater Interactions; Reclaimed Water Issues; Groundwater Management Plans; Insitu Remediation Techniques; and Risk-Based Corrective Action. In addition to our speakers, we had a few poster presentations that were very professionally presented and quite informative. Our keynote speakers provided stimulating discussions that carried on into other talks (See Dr. Joseph Birman's presentation in this Hydrovisions). As a result of these keynote presentations, many of us are armed for performing interplanetary groundwater evaluations for the next millennium (Dr. David Senske's presentation on Jupiter's Moons). Our Exhibitors, once again, out did themselves and provided technically focused exhibits that satiated our scientific curiosity (see our list of Exhibitors in this issue of *HYDROVISIONS).*

GRA thanks all our speakers, poster session presenters, exhibitors, meeting sponsors, moderators and other helpers for making the annual meeting such a memorable event. We would like to provide special acknowledgments to Carl Hauge of the California Department of Water Resources for assisting us in developing a strong speaker program, and Dr. E. Essi Esmaili of Foster Wheeler Environmental for an excellent Risk-Based Corrective Action Workshop. GRA would also like to thank the Southern California Branch for producing the annual meeting. In particular, we would like to thank Jim Carter, Mark Cutler, Carmen Guzman, and Lou Reimer for all their efforts. Special thanks to Bas (Berge Basmadgian) for the wonderful graphics. A heartfelt thanks goes to Vicki Kretsinger for support and advice. Lastly, I would like to thank my employer, Foster Wheeler Environmental for all their assistance in finalizing the publications for the meeting and for supporting my efforts concerning the annual meeting.

### *Forthcoming Events*

Our 1997 Annual Meeting will be held during the third week of September 1997, in Sacramento, California. The meeting will be held jointly with the University of California Water Resources Center's Biennial Ground Water Conference. We look forward to this event and are seeking individuals to assist on GRA's Planning Committee. Interested individuals should contact Anthony Saracino, GRA's 1997 Annual Meeting Chair.

Also forthcoming in 1997, there will be two Seminars/Workshops. We are currently seeking individuals who can assist in organizing these technically informative one-day events. Contact me if you are interested.

Thank you for the wonderful year as President. I have enjoyed working with all of you this year and look forward to working with you in 1997. Have a wonderful and safe Holiday Season.

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## Exhibitors:

Identified below are the Exhibitors for GRA's Fifth Annual Meeting. GRA thanks these individuals for their continued support. The Exhibitors are listed below in alphabetical order.

**Colorado Silica Sand Inc.**
P. O. Box 15615
Colorado Springs, CO 80935
PH. 719/390-7969
Fax 719/390-5517

**Columbia Analytical Services**
6925 Canoga Avenue
Canoga Park, CA 91304
PH. 800/695-7222
Fax 818/587-5555

**Gregg Drilling & Testing**
2475 Cerritos California
Signal Hill, CA 90806
PH. 310/427-6899
Fax 310/427-3314

**Instrumentation Northwest, Inc.**
4620 Northgate Blvd., Suite 170
Sacramento, CA 95834
PH. 800/776-9355
Fax 916/648-7766

**Johnson Screens**
P. O. Box
Saint Paul, MN
PH. 612/638-3159
Fax 612/638-3140

**Layne Christensen Company**
16018 Valley Blvd.
Fontana, CA 92335
PH. 909/355-3355
Fax 909/355-7640

**Roscoe Moss Company**
4360 Worth Street
Los Angeles CA 90063
PH. 213/263-4111
Fax 213/263-4497

**SPL Laboratories**
1511 E. Orangethorpe Ave.
Fullerton, CA 92831
PH. 714/447-6868
Fax 714/447-6800

**Welenco, Inc.**
4817 District Blvd.
Bakersfield, CA 93313

PH. 805/834-8100
Fax 805/834-2550

**Westbay Instruments, Inc.**
#115-949 West Third Street
North Vancouver, BC V7P 37P
PH. 604/984-4215
Fax 604/984-3538

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# SYMPOSIUM ON NATURAL ATTENUATION OF CHLORINATED SOLVENTS IN GROUNDWATER - A SUMMARY

*by Tim Parker & Tom Mohr*

## INTRODUCTION

Since the mid-1980s, the environmental industry has mounted a tremendous effort to mitigate groundwater contamination, reaching some $10 billion per year in the 1990's. Critical technical review of this very costly groundwater restoration effort by the National Research Council (1994) indicates few successes have been achieved to date, for several reasons including:

- Stringent drinking water standards (maximum contaminant levels or MCLs), which were originally intended for public water supplies, were selected as cleanup goals with the naïve expectation that existing technology could meet these goals
- Pump-and-treat was the primary technology applied to quickly cleaning up groundwater to the MCLs
- Pump-and-treat did not perform as projected due to:

    1. Subsurface physical heterogeneity and complex contaminant migration pathways, which are extremely difficult if not impossible to evaluate adequately
    2. Non-aqueous phase liquids (NAPLs) present in the saturated zone are not efficiently removed by pumping groundwater
    3. Contaminant recovery generally controlled not by the rate of groundwater flow, but by the rate of diffusion from inaccessible regions of the saturated zone to which contaminants have migrated
    4. Sorption of contaminants to subsurface materials has generally been unaccounted for, which has resulted in an underestimation of the total contaminant mass that must be removed and time needed for restoration
    5. Difficulties involved with characterizing subsurface heterogeneity has resulted in increased uncertainty in engineered remedial actions.

The best available technology for restoration of chlorinated solvent impacted soil and groundwater seems to include a handful of remedial alternatives or combinations thereof: soil vapor extraction, bioventing, in situ bioremediation, surfactants, two-phase extraction, passive barriers, and engineered microorganisms. While application of these technologies help to reduce the contaminant mass, all of these technologies are limited in their ability to perform. With the exception of very few "simple sites," there is currently no existing technology that can be applied to restore chlorinated solvent impacted groundwater to drinking water standards. However, over the past 10 to 15 years it has been observed that in some cases, the chlorinated solvent plume has not continued to migrate, but in fact has reached equilibrium in a relatively short distance. A closer look at many of these sites indicates that remediation is occurring by natural attenuation; in other words, that natural biogeochemical processes have caused the contaminants to break down to non-hazardous components.

Natural attenuation of chlorinated organics in groundwater was the subject of the September 1996 symposium that the two authors of this article were fortunate enough to attend. The symposium took place over three days in Dallas, Texas, and was sponsored by the U.S. EPA, the Air Force Center for Environmental Excellence (AFCEE), and US Air Force Armstrong Laboratory. This article is our attempt to provide ***HYDROVISIONS*** readers with a brief overview of some of the information provided at the symposium.

## WHAT IS NATURAL ATTENUATION ?

"The biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that

are protective of human health and the ecosystem" (U.S. EPA Office of Research and Development and Office of Solid Waste and Emergency Response). Also referred to as intrinsic remediation, intrinsic bioremediation, or passive remediation, the current "trend" for consistency is to call it remediation by natural attenuation (RNA). In groundwater, natural attenuation typically occurs through destructive (for example biodegradation) or non-destructive mechanisms (e.g., sorption, dispersion, dilution, volatilization). Biodegradation of fuel hydrocarbons, especially the aromatics (BTEX), is mainly limited by electron acceptors and with few exceptions will proceed to complete destruction. However, biodegradation of chlorinated solvents (e.g., PCE, TCE) most commonly occurs via reductive dechlorination, a process that requires both electron acceptors (chlorinated aliphatic hydrocarbons) and an adequate supply of electron donors (natural organic carbon, fuel hydrocarbons, landfill leachate) in order to proceed to complete destruction.

## BIODEGRADATION OF CHLORINATED SOLVENTS

Chlorinated solvents undergo biodegradation through three different pathways: (1) use as an electron acceptor (reductive dechlorination); (2) use as an electron donor (primary substrate); (3) co-metabolism where degradation of the chlorinated solvent provides no benefit to the microorganism but is simply fortuitous. In general, biodegradation of chlorinated solvents is an electron-donor-limited process.

The generalized process of biodegradation of chlorinated solvents begins in the saturated subsurface where native/anthropogenic carbon is utilized as an electron donor, and dissolved oxygen is utilized first for the prime electron acceptor. Once the dissolved oxygen is depleted, anaerobic microorganisms typically utilize additional available electron acceptors in the following order: nitrate, ferric iron hydroxide, sulfate, and carbon dioxide. In the absence of nitrate and dissolved oxygen, chlorinated solvents compete with other electron acceptors and donors, especially sulfate and carbon dioxide. By looking at the spatial distribution and concentrations of electron acceptors and donors, the mechanism(s) and rates of biodegradation can be assessed.

The most important process for the natural biodegradation of chlorinated solvents is reductive dechlorination. The chlorinated solvent is utilized as an electron acceptor, and a chlorine atom is removed and replaced with a hydrogen atom. Because chlorinated solvents are utilized as electron acceptors during reductive dechlorination, an appropriate carbon source is required for microbial growth to occur. Reductive dechlorination has been demonstrated under nitrate- and sulfate-reducing conditions, but the highest rates of biodegradation occur during methanogenic conditions.

A less consequential natural biodegradation process for chlorinated solvents is as a primary substrate or electron donor reaction. Under aerobic and in some cases anaerobic conditions, less-oxidized chlorinated solvents (1,2-DCA and vinyl chloride) can be utilized as a primary substrate in biologically mediated redox reactions. The facilitating microorganisms obtain energy and carbon from the degraded chlorinated solvent in this process.

Co-metabolism is another natural degradation process for chlorinated solvents in the saturated subsurface, albeit much less consequential. The process of co-metabolism of chlorinated solvents has been best documented in cases where fuel hydrocarbons including BTEX are present with the chlorinated solvents. The chlorinated solvents are indirectly transformed by bacteria as they use the BTEX or another substrate to meet their energy requirements.

## CHLORINATED SOLVENT PLUME BEHAVIOR

The behavior of chlorinated solvent plumes is dependent upon several elements of the biogeochemistry of the aqueous subsurface environment: (a) mass and concentration of solvent present, (b) amount of biologically available organic carbon, (c) distribution and concentration of natural electron acceptors, (d) types of electron acceptors being used. The behavior of solvent plumes has been categorized into three types: (Type 1) primary substrate is anthropogenic carbon (e.g., fuel hydrocarbons, landfill leachate) and anthropogenic carbon drives the reductive dehalogenation; (Type 2) primary substrate is native organic carbon and native carbon drives the reductive dehalogenation; (Type 3) primary substrate of carbon

essentially absent (no natural or anthropogenic source available), dissolved oxygen concentrations greater than 1 milligram per liter. Conditions conducive to RNA are represented by rapid and extensive reductive dehalogenation with Type 1 plumes, and slow to rapid reductive dehalogenation with Type 2 plumes. In Type 3 plumes, reductive dehalogenation is absent and natural attenuation occurs predominantly by advection, dispersion, and sorption; however, vinyl chloride can be rapidly oxidized.

Generally what occurs is a mixture of complex plume behaviors. For example, Type 1 behavior may be exhibited in the near-source area, with fuel hydrocarbon degradation accompanied by breakdown of PCE and TCE to DCE. Downgradient, with the disappearance of fuel hydrocarbons and primary substrate, behavior is represented by the presence of DCE and no other daughter products. A preferred plume behavior combination is to have a Type 1 in the source area with the majority of reductive dechlorination occurring there, and the degradation of the chlorinated solvents to vinyl chloride and ethene. Downgradient of the Type 1 zone, a Type 3 oxidizing zone would provide the mechanism to degrade the vinyl chloride to carbon dioxide and chloride.

## CHARACTERIZING FOR RNA

The characterization of natural attenuation of chlorinated solvents sites requires very detailed and calculated monitoring. In the opinion of Dr. John Cherry of the University of Waterloo, what by appearance is suggested to be natural attenuation of chlorinated solvents may in fact be a result of inadequate site characterization or poor monitoring. Cherry's work characterizing chlorinated solvent plumes in the Borden aquifer, Canada, indicates that even in a relatively homogeneous sandy aquifer, the core of the plume may occur in a very discrete zone on the order of a foot or so thick. For this reason, identification of the plume core cannot necessarily be expected to be accomplished with conventional monitoring well networks and construction. Detailed investigations involving direct push technology at vertical intervals as small as one foot to assemble three-dimensional transects are necessary to elucidate contaminant distribution patterns. Cherry suggests that the emphasis of site characterization data collection should be on detailed spatial rather than temporal data, and that the most economic way to collect the finer grid spatial data is with direct push technology, collecting of soil cores and discrete groundwater samples during vertical advancement of the probe.

For RNA investigations, it is necessary to determine which reactions and processes are driving the subsurface biogeochemistry. General physical parameters include oxidation-reduction potential, temperature, pH, field-titrated alkalinity, and conductivity. Additional chemical parameters include the dissolved oxygen, nitrate, nitrite, ferric iron, ferrous iron, sulfate, sulfide, chloride, total organic carbon (TOC), fuel hydrocarbons, aromatic and chlorinated solvents. In the RNA context, TOC is a measure of the total electron donor capacity of the saturate subsurface. Some practitioners recommend using dissolved organic carbon, excluding carbonates with acid, to more accurately estimate total electron donor capacity. Dissolved molecular hydrogen, methane, ethane and ethene are also necessary components of a natural attenuation monitoring program. The technique for quantifying dissolved molecular hydrogen involves bubbling extracted groundwater in the field using a flow through gas stripping device and analyzing with a properly equipped field gas chromatograph. The range of hydrogen concentrations is indicative of the particular biodegradation process occurring (nitrate reduction, iron reduction, sulfate reduction, methanogenic).

An additional element to consider is the completion of microcosm studies to assess if the microorganisms necessary for biodegradation are present and to help quantify rates of biodegradation. Simplistically, microcosm studies amount to collecting subsurface soil samples, placing the soil samples under a controlled laboratory environment, injecting known contaminants into the samples, and measuring the changes in concentration over time, allowing estimation of biodegradation rates. Microcosm studies are time-consuming, expensive, and are generally recommended only when there is a considerable need to demonstrate the presence of the microorganisms. However, if properly designed, implemented and evaluated, microcosm studies can provide very convincing evidence on the presence and rates of biodegradation. It has been suggested that biodegradation rate constants determined by microcosm studies may be much higher than actual in situ rates. Therefore, the preferable method is to determine the

contaminant biodegradation rate constant via in situ field measurement.

## CASE STUDIES

**Naval Air Station Cecil Field, Florida** Documentation of RNA at Naval Air Station Cecil Field in Florida is provided by the segregated sequence of redox processes into distinct zones, where reductive dehalogenation of chlorinated ethenes occurs near the contaminant source, followed by oxidative degradation of vinyl chloride to carbon dioxide and chloride downgradient. Near the contaminant source, methanogenesis predominates. Moving downgradient, distinct sulfate-reducing, iron (II)-reducing, and oxygen-reducing zones are evident.

**St. Joseph, Michigan Superfund Site** Groundwater flows at the St. Joseph site from the contaminant source toward Lake Michigan. The average hydraulic conductivity was estimated at 7.5 meters per day, the estimated travel time for TCE in groundwater is 18 years, and if the contaminant was released only as an aqueous phase, it should have reached the lake by now. The observed contaminant concentration and distribution suggests a continuing DNAPL source. Evidence of RNA is provided by segregated methanogenic and oxygenated zones of the saturated subsurface. Anaerobic degradation of TCE occurs through a successive dechlorination from TCE to DCE to vinyl chloride and ethene. High cis-DCE concentrations were generally associated with declines in oxygen and sulfate concentrations and appeared on the upper edge of the methanogenic zone. TCE concentration decreased by a factor of 50,000, and all contaminants decreased to values below the MCL before they reached the lake. Mass fluxes decreased by factors of 10 to 123. Apparent degradation rate constants were estimated from a two-dimensional model at 0.3 to 1.7 for TCE, 0.54 to 4.0 for cis-DCE, and 2.6 to 20 for vinyl chloride.

**Plattsburg Air Force Base, New York** Soil and groundwater were contaminated by fuel hydrocarbons and chlorinated solvents at a former fire training area at Plattsburg Air Force Base, New York. Groundwater contaminants include TCE, cis-1,2-DCE, vinyl chloride, and BTEX. Depth to groundwater ranges from 45 feet bgs to the west and ground surface to the east, and groundwater flows to the southeast at approximately 140 feet per year. Available biogeochemical data indicate two separate plume behavior categories at the site. In the source area and extending approximately 1,500 feet downgradient, the presence of commingled BTEX and TCE is characterized by anaerobic conditions that are strongly reducing (Type 1 behavior). Dissolved oxygen concentrations are on the order of 0.1 mg/L (background 10 mg/L), nitrate approximately 0.1 mg/L (background 10 mg/L), iron (II) 15 mg/L (background 0.05 mg/L), sulfate 0.05 mg/L (background 25 mg/L), methane at 3.5 mg/L, hydrogen from 1.4 to 11 nanomoles. The hydrogen concentrations are indicative of sulfate reduction and methanogenesis even though there is no sulfate available and relatively little methane produced, thus suggesting that reductive dechlorination may be competitively excluding these processes. In this area BTEX is being used as the primary substrate and TCE is being reductively dechlorinated to cis-1,2-DCE and vinyl chloride. Extending from approximately 1,500 to 2,000 feet downgradient of the source, the majority of the BTEX has been degraded, and the plume is characterized by conditions suggestive of Type 3 plume behavior. Dissolved oxygen concentrations are on the order of 0.5 mg/L (background 10 mg/L), nitrate increasing to background level of 10 mg/L at plume end, iron (II) decreased to 1 mg/L (background 0.05 mg/L), sulfate increasing to 15 mg/L (background 25 mg/L), and hydrogen from 0.8 to 0.25 nanomoles. The hydrogen concentrations are indicative of iron (III) reduction.

**Picatinny Arsenal, New Jersey** A solvent plume at this site occupies an area approximately 500 m long by 250 m wide, in a shallow, 20 m thick unconfined sandy aquifer in which groundwater flows at an estimated velocity of 0.3 to 1 m/yr. Thirty years of degreasing activities in one location have released an estimated 3,500 kg of TCE into the aquifer. Maximum concentrations of TCE in groundwater occur near the base of the aquifer, midway along the centerline of the plume, at 10,000 µg/L. Characterization of parameters indicative of natural attenuation found dissolved oxygen at less than 0.5 mg/L, nitrate less than 1 mg/L, ferric iron > 1 mg/L, abundant sulfate and carbon dioxide (measured as alkalinity), noticeable hydrogen sulfide smell, and dissolved methane concentrations at 1 to 85 µg/L. These findings strongly support the conclusion that anaerobic biologic processes are predominant at different stages, and their

spatial distribution suggests different redox processes are present at different locations. Dissolved organic carbon is contributed from natural sources as fulvic and humic acids. The presence of cis-1,2-DCE and vinyl chloride, solvents not used at the site, are further indicative of reductive dehalogenation. Investigators at this site identified the distribution of the solvent mass in different phases, and estimated the means by which solvent mass is actively being reduced. The ratio of sorbed to dissolved solvent is about 3:1 to 4:1. An estimated 50 kilogram per year (kg/yr) is discharged to a stream at the toe of the plume, 1 kg/yr spreads laterally to concentrations below the plume boundary definition (10 µg/L), 360 kg/yr is removed by natural anaerobic biotransformation, 50 kg/yr is lost to advective-driven volatilization, and less than 1 kg/yr each are attributed to diffusion driven volatilization and to sorption. While 460 kg/yr are lost, primarily due to natural anaerobic bioattenuation, 550 kg/yr are added due to desorption of solvent from the most concentrated core of the plume. In contrast, traditional pump and treat technologies active at this site remove about 70 kg/yr, at an estimated cost of $700,000/yr. Natural attenuation has been proposed as the principal mechanism for the removal of TCE from the Picatinny Arsenal plume.

## WILL REGULATORY AGENCIES ACCEPT RNA?

There have been over 90 U.S. EPA Records of Decisions with RNA as either the selected alternative, or an element of the selected remedy for the site (through 1995). About one-third of these sites are landfills. According to U.S. EPA, RNA is not a "no action" alternative for RP's to walk away from a site. In fact, demonstrating the effectiveness of remedies involving natural attenuation will require more thorough site characterization, detailed monitoring of the remedial progress, and contingency measures to ensure long-term reliability and protection of human health and the ecosystem. There are currently two states with RNA policies: North Carolina and New Jersey. Approximately one-third of the states favorably support RNA and are in the process of developing state policies - California to our knowledge is not one of these states. U.S. EPA will be issuing a federal policy on RNA either the end of 1996 or the beginning of 1997. The American Society for Testing & Materials (ASTM) is in the process of developing an ASTM Standard on RNA.

In the future, groundwater restoration strategies have to be better, smarter, and cheaper. This means better application of the scientific data and knowledge collected over the last fifteen years to utilize combined smarter strategies resulting in cheaper remedies to groundwater pollution problems. Better application of data may mean improved site characterizations with sophisticated sampling techniques, new analytical approaches, and state-of-the-art groundwater modeling to more accurately predict the contaminant fate and transport. Smarter strategies may mean combining source removal, source control/containment, and RNA to acceptably manage the risk of exposure. Cheaper as compared to pump & treat for decades may include assessing the net-benefit of actually restoring the groundwater resource to drinking water supply MCLs. In this industry, one thing is certain: "the future just ain't what it used to be."

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