Minnesota Ground Water Association

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The President's Page

We all want to "do the right thing." We use our analytical skills, our experience, and other tools to find answers, make decisions, and provide advice. The "right thing" isn't always clear and certainly isn't always the easiest choice. We have recently heard about individuals in the savings and loan industry, and other professions, who have not always made responsible decisions on behalf of their clients or professions.

Good intentions can get lost when competitive pressures, conflicting interests, and overwhelming work loads divert our ability to focus. Although no company or organization purposefully designs jobs or projects to pose ethical dilemmas, they arise all the same. Examples are familiar to us all:

1) An irrigator's appropriation permit is up for renewal. The possibility that her pumping will have an adverse impact on nearby residential wells at the present level of pumping is quite high, but still uncertain. But upon further examination, you realize that if the permit is not renewed, given the sandy soils in that area, crops will fail with resulting economic impact, and the life style impact on that farmer and her family will be tremendous.

Faced with the uncertainty of the hydrologic analysis and the potential impact to other homeowners, you must make tough choices.

2) The analytical results from recent ground water monitoring come across the consultant's desk. The results indicate that an unforseen contaminant problem at the client's site is migrating toward a nearby municipal well. The client directs you to discontinue monitoring. Your contract with the client requires confidentiality. Do you breach the contract or do you allow the potential impact to the city well to continue? For you individually, this situation may pose several alternatives: do nothing; call the city or regulators and breach the contract; rely on the client to report the threat; or other options. The actions that you take could also affect many others including your co-workers, your clients and their employees, and the citizens of the city.

The point here is not to detail a variety of situational dilemmas. It is not possible to give right or wrong answers for many situations we encounter. Conditions, circumstances, and perceptions change. We all develop our own internal "compasses" to tell us what direction we must take at decision points. By knowing yourself and where to find your compass, it should be easier to make the best decision.

-- Bob Karls

Dr. Jay Lehr to Speak at November Risk Assessment Conference

The Minnesota Ground Water Association will host a one day conference on November 14, 1990, entitled "**Environmental Risks - Contrasting Perceptions.**" The purpose of this conference will be to offer a forum where differing viewpoints on the extent of risk posed by environmental contaminants can be discussed and questioned.

Dr. Jay Lehr, Executive Director of the National Water Well Association, Dr. Vernon Houk, Director of the Center for Environmental Health and Injury Control - Centers for Disease Control, and Janet Hathaway of the Natural Resources Defense Council have agreed to speak at the conference. At the time this newsletter is being prepared, we are awaiting a response from the invited speaker from the Sierra Club.

Dr. Lehr, in a recent series of editorials in *Ground Water*, the journal of the Association of Ground Water Scientists and Engineers, presented some strong opinions on current regulations, risk communication, and the activities of several environmental organizations. Some of these organizations and some agencies involved in risk management and assessment have responded to Dr. Lehr's comments in Letters to the Editor which have been published in *Ground Water* over the last several months:

"Are Regulators Dinosaurs? -- Are we getting to the point, by making our ground water standards so stringent, that some day our bodies will be so acclimated to purity that one sip of water with 15 to 20 parts per million nitrate will indeed be deadly to us? -- we should be a little more realistic and recognize that

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Innovative Techniques for In-Situ Remediation

by Larry Murdoch, University of Cincinnati, U.S. EPA Solid and Hazardous Waste Research Facility

Delivery and recovery techniques have been used for many years to remediate contaminated sites. Existing techniques are usually ineffective at sites with contaminants that are insoluble in water or that are readily adsorbed to soil. Low hydraulic conductivities and localized stagnant zones further inhibit the rates and effectiveness of delivery or recovery.

Innovative technologies currently under investigation or that show some potential were reviewed for possible application in ground water remediation. The use of **colloidal gas aphorns (CGA)** has been suggested as a technique to enhance the in-situ aerobic biodegradation of dissolved and dispersed organic contaminants.

Hydraulic fracturing is a process of cracking rock by injecting water or other fluid at pressures exceeding the confining stress in the neighborhood of a borehole. Sand is then pumped in to hold the fracture open and create high-permeability channels. This technique could be used to increase rates of delivery or recovery of contaminated soil or rock from a well.

In **radial well drilling**, horizontal wells are placed radially outward from a central borehole (4.5 inches in diameter or larger). The horizontal radial is cut by high velocity water pumped from a conical jet nozzle fed from the surface with steel tubing. Radial wells are used to enhace access to a contaminated formation or aquifer for in-situ treatment.

Ultrasonic vibration is used to disperse clay and silt particles under laboratory conditions. Possible applications of ultrasonic vibration to remedial actions include

- dispersing clay particles clogging soil pores adjacent to wells;
- reducing adsorption of contaminants onto the surfaces of clays, and
- eliminating microorganisms clogging soil pores adjacent to wells.

Kerfing, or borehole notching, involves cutting a slot either normal or parallel to the axis of a borehole. A high pressure jet of water, water and air, water and bentonite, or water and abrasives, is used to cut the slot. This technique originally attracted attention as a control technique, but may be useful in recovery as well.

Electro-osmosis, or electro-kinetics, occurs when a liquid migrates through a charged porous medium under the action of an electric field. The electric field is applied through anodes that cause the cations to migrate through the saturated medium towards the negatively charged cathodes. Electro-kinetics has the potential for delivering remediating materials and recovering spent solutions or contaminants, principally metals, from contaminated soil.

Jet-induced slurry excavation generates a high-velocity hydraulic jet that erodes subsurface material and pumps the slurry through a well to the surface for processing. Contaminated material could be recovered from the subsurface without removing the overburden.

In-situ steam stripping is a method for recovering highly volatile and also moderately low vapor pressure organic compounds from the contaminated soil. The injected steam releases heat to the soil when it condenses. The steam vaporizes the contaminants that would be immobile at ambient temperatures and becomes the transport medium for the vaporized compounds.

In-situ combustion is used to recover crude oil from tar sand and other deposits of viscous hydrocarbons. In-situ combustion uses an injection and production well system to create and move a thermal front through a formation. Lighter fractions are mobilized through volatilization and reduced viscosity. Similar technicques could possibly be used to recover hydrocarbons from hazardous waste sites.

Cyclic pumping is a delivery or recovery techniqe that systematically varies rates of either injection or extraction. Pumps are turned on and off in sequential cycles. A rest cycle allows time for diffusion between high-permeability pathways and the low-permeability blocks between them. An active cycle is designed to deliver the minimum volume of nutrients or reactants or to remove the maximum possible concentration of reaction products. Optimized pumping has the potential to reduce costs.

In-situ soil flushing accelerates the movement of a contaminant through unsaturated materials. A particular treatment solution is applied to the soil and percolates downward to interact with contaminating chemicals. Contaminants

Fall Meeting

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many of the substances that we are trying to monitor and restrict may have been present in our environment for thousands of years -- Is some contamination and pollution actually healthy?" *-Darrel Plummer, Kansas Water Well Program*

"So-called 'chemophobia' has evolved over the past several decades as the result, in part, of inadequate representations of chemicals' potential environmental and human health impacts. Past public pronouncements that 'there's no risk, don't worry, be happy' when there were legitimate health concerns associated with exposure to chemicals has led to widespread distrust of such messages." *-David Belluck, Dunn Geoscience*

Formal addresses by each of the speakers will be followed by moderated panel discussions. Lunch will be provided.

The conference will be held at the Thunderbird Hotel in Bloomington. The program begins at 8:30 a.m., registration begins at 8:00 a.m. The fee of $40 pays for the facility, lunch, and the expenses of our speakers. Registration is limited and advance registration is highly recommended. The conference registration form is on page 19.

are mobilized and transported downward to a saturated zone where they are pumped to the surface.

Artificial ground freezing may concentrate contaminants ahead of freezing fronts, thus reducing the volume of contaminated soil.

Other innovative techniqes which may be useful in ground water remediation procedures include vapor extraction, carbon dioxide flooding, hot-brine injection, and the addition of water-soluble polymers.

Reprinted from the Bulletin of the American Institute of Hydrology, Vol. 8, No. 3. The project report was published as *Technology of Delivery or Recovery for the Remediation of Hazardous Waste Sites,*

1990 Minnesota Gound Water Bibliography

The Minnesota Department of Natural Resources has updated the *Minnesota Ground Water Bibliography*. The 1990 version is completely revised and updated. It contains over 100 pages of references listed by hydrologic subject area and Minnesota region (where region is defined by the six DNR regions).

It includes a helpful index and directory of agencies and organizations involved in ground water investigations or regulation.

The *Minnesota Ground Water Bibliography* may be requested free of charge from DNR - Division of Waters, Ground Water Unit, 500 Lafayette Road, St. Paul, MN 55155.

In addition to paper copy, the *Minnesota Ground Water Bibliography* can also be supplied in electronic form for MS/DOS computers in the following formats: MS Word for Windows or DOS and ASCII text. Please send a blank formatted MS/DOS disk with such requests. Users of word processors with a search function will find that it will be possible to search the bibliography for key words very quickly

Continuing Education Credits Granted

Two continuing education hours toward the renewal of a water well license or a monitoring contractor registration were granted for attendees of the **MGWA Field Techniques and Data Interpretation Seminar** held Monday May 7, 1990. This was confirmed in a letter from James D. Nye, Supervisor of the Well Management Unit of the Minnesota Department of Health. Contact James D. Nye at (612) 627-5154 with any questions.

Pump-And-Treat Report Available

A common means to contain and/or remediate contaminated ground water is extracting the water and treating it at the surface, which is referred to as pump-and-treat technology. GeoTrans, Inc. recently wrote a report for the USEPA on pump-and-treat technology. This report provides basic guidance on how to use available hydrogeological and chemical data to determine when, where, and how pump-and-treat technology can be used successfully to contain and/or remediate contaminate plumes. Ways to estimate the time required to achieve a specific ground water cleanup goal are also discussed. Finally, the report addresses practical limitations of pump-and-treat technology given certain combinations of hydrogeologic conditions and geochemical properties. The report reference is:

Mercer, J.W., D.C. Skipp and D. Griffin, 1990, *Basics of Pump-and-Treat Ground-Water Remediation Technology*, U.S. Environmental Protection Agency EPA/600/8-90/003, Ada, Oklahoma.

This report on pump-and-treat technology may be ordered through the EPA Office of Research and Development, Publication Distribution Office at (513) 569-7562.

(Reprinted from GeoTrans, Inc. Newsletter, Spring 1990)

Underground Storage Tank Notification

The Minnesota Pollution Control Agency (MPCA) requires written notification from owners of underground storage tanks (UST's) within 30 days of tank installation. The required notification includes information on the size (volume), type of tank material, tank contents, location, and use.

Owners of tanks installed after 1973, whether the tank is in use or out of service, must also notify the MPCA and supply the information as listed above.

Septic tanks, residential tanks smaller than 1100 gallons used for heating oil or motor oil, tanks above the floor in a basement and pipeline facilities are exempt from the notification requirement.

Within 30 days of tank removal or a change in the tank's status, contents, use or ownership, the MPCA must be renotified. The types of tank status are: in service, temporarily out of service (<1 year), permanently out of service (>1 year), abandoned in place, or removed. In the case of a change in ownership, it is the new owner's responsibility to notify the agency.

The UST Notification Form is available free from the MPCA Hazardous Waste Division, Tanks and Spills Section, 520 Lafayette Road, St. Paul MN 55155; (612) 643-3413. There is no notification fee.

Local ordinances may impose tighter restrictions. For example, according to Alan Nelson, Fire Marshal of the City of New Hope, out of service tanks in the City of New Hope must be removed or put back in service within 90 davs.

Reprinted from the EnPro Environmental Profile 1990, Volume 2, Number 1.

The MGS Prairie du Chien-Jordan Study

The Minnesota Geological Survey is participating in a multi-agency cooperative effort to identify natural geologic and hydrogeologic factors that affect the sensitivity of ground water to contamination.

The goal is to develop criteria and methods for assessing ground water sensitivity and to generate a handbook and other educational materials, which will be used by planners to make such assessments.

The Survey's contribution is the investigation of the distribution of contamination in aquifers and the geologic factors that affect its introduction and migration. The subcrop area of the Prairie du Chien-Jordan aquifer (that area where the Prairie du Chien or Jordan Sandstone forms the first bedrock beneath glacial materials) was chosen for the pilot study.

The project involves several separate activities and many Survey employees. Howard Hobbs is serving on a committee that has generated preliminary criteria and drafted guidelines for assessing ground water sensitivity. John Mossler, Roman Kanivetsky, Howard Hobbs, Jane Cleland, Bob Tipping, and Tony Runkel are mapping the geology and hydrogeology in the subcrop area of the Prairie du Chien Group and the Jordan Sandstone, which together form the aquifer under study.

Various maps are being generated at the scale of 1:250,000; they include bedrock thickness and structure, potentiometric surface of the aquifer, glacial-drift character and thickness, and nitrate levels. The physical characteristics of the bedrock units are being investigated with gamma logging and outcrop studies.

The mapping of geologic conditions will be correlated with the map of nitrate contamination and the results used to test and refine the final sensitivity criteria and guidelines. The Survey mapping is also being used as a framework for more site-specific studies, which are being conducted by other cooperating agencies.

The first year of the two year project is finished. The mapping of bedrock thickness and structure is complete, as is the map of the potentiometric surface. The glacial mapping is underway, and the data for the nitrate map are being processed. Gamma logging in the Prairie du Chien and Jordan continues and outcrop studies have started; both activities will augment the information already collected and aid its interpretation.

The ground water sensitivity project is funded by the Legislative Committee on Minnesota Resources and is being carried out in cooperation with the Ground Water Unit of the Division of Waters, Minnesota Department of Natural Resources. Dale Setterholm coordinates the Survey's contribution; Sarah Tufford or Jan Falteisek can be contacted at the DNR. All work will be completed by June 30, 1991.

from the Minnesota Gelogical Survey Newsletter, Summer 1990

Environmental Telephone Directory Available

The *1990-1991 Edition of the Environmental Telephone Directory* is now available to help find the proper contacts on federal and state environmental laws, regulations and policies. This new 1990-1991 edition has been completely updated with the most current names, phone numbers, and addresses of key environmental contacts.

It includes:

(1) U.S. senators and representatives, with their environmental aides and state and district offices,

(2) U.S. Senate and House committees and subcommittees dealing with environmental issues,

(3) U.S. Environmental Protection Agency staff, containing both headquarters and regional organizational listings as well as a helpful *Headquarters Subject Directory*,

(4) other federal and executive agencies dealing with the environment, listing key contacts, regional administrators, and general information numbers, and

(5) state environmental agencies, detailing each state's specific organizational structure for handling environmental matters.The 256-page softcover *1990-1991 Environmental Telephone Directory* is available for $55 (plus $3 shipping and handling U.S./$5 elsewhere) from Government Institutes, Inc., 966 Hungerford Dr. #24, Rockville, MD 20850; (301) 251-9250.

Monitoring Well Course

Minnesota Department of Health will be sponsoring a one day course about monitoring wells to be held on Tuesday, November 13, at the Thunderbird Hotel in Bloomington, Minnesota (2200 E. 78th Street).

Subjects to be covered are: monitoring well law and rules, at grade installation, new technology, monitoring well leakage, monitoring well abandonment, sampling and geophysical monitoring. Six hours of continuing education credits will be awarded to persons licensed or registered by Minnesota Department of Health's Well Management Unit towards the annual renewal of licenses.

The fee, $35, which includes materials, refreshments and lunch, should be sent to Minnesota Department of Health, Well Management Unit, 925 Delaware Street, SE, P.O. Box 59040, Minneapolis, Minnesota 55459-0040 before November 5, 1990.

Contact Roman Koch at (612) 627-5153 with any questions. The Thunderbird Hotel's phone number is (612) 854-3411.

Estimation of the Duration of Ground Water Contamination Pump-Outs.

by Donald F. Kidd and Randall R. Miller, Delta Environmental Consultants, Inc.

Abstract

Prediction of the time needed to clean up an aquifer is difficult without extensive field work and/or historical data. An estimate must often be made before ground water extraction begins. Input parameters needed for calibration of ground water contaminant transport models are frequently not available. The purpose of this study was to evaluate project life estimation methods and to compare the relative efficiency of ground water recovery alternatives.

Three models were compared: a Random-Walk dispersion model, a Method of Characteristics (MOC) contaminant transport model and a model which simulates the contaminated aquifer as a mixed tank.

Calibration, input parameters, and prediction accuracy vary, but each model can provide cost-effective predictions without extensive field work. Proper application of the predictions, however, is contingent upon an understanding of the assumptions and limitations of the models.

Introduction

Aquifer restoration methods are often decided upon in the early stages of a project. If all available data are incorporated into the design, it is more likely that the project will effectively address the contamination in a cost-effective and timely manner. Modeling can aid project design by predicting long term effects of the selected remedial alternative.

Project life is a major factor in the cost of operating and monitoring remedial actions. Present worth analysis can be used to calculate relative costs when comparing two or more remedial alternatives. Present worth is a standard method of comparing the cost of alternatives over the life of a project, taking the time value of money into account.

This study illustrates possible methods of estimating project life for remediation of a gasoline contaminated aquifer where ground water extraction is the recovery method.

Modeling Process

A petroleum release site in southwest Florida provided data for calibration. The output from each of the models was compared with data collected from subsequent remedial actions at the site. Approximately one year of remedial data was available for comparison with the predictions.

Each of the models assumes single phase transport of the dissolved contaminants and does not account for free floating product. It was assumed that the free product would be removed in the early stages of the project and would not significantly alter the predicted project life. This assumption was validated when essentially all the free product at the site was recovered within the first five months of recovery well operation.

Plots of predicted recovery well concentrations were extrapolated to predict the time needed to reduce concentrations to 1 part per billion.

The models were provided with identical inputs when at all possible. Literature values typical of the studied hydrogeologic setting were used for parameters not measured in the field (SFWMD, 1988). Although there are uncertainties associated with these data, all models were expected to be equally affected. Table 1 presents the aquifer parameters as used in the three models.

Adsorption of molecules onto the soil is accounted for in analytical models using a retardation coefficient. The retardation coefficient effectively reduces the velocity of the contaminant relative to ground water flow:

$R = V_w/V_c$ (Prickett, 1981)

where:

R = retardation coefficient

V_w = velocity of water

V_c = velocity of contaminant

Retardation is a function of the contaminant properties and soil type. Sorption/desorption of the contaminants has been shown to have a significant effect on the rate and ultimate level of clean-up which can be cost-effectively achieved (API, 1986).

Benzene was selected as the controlling compound for project life estimation primarily because benzene is subject to relatively strict regulatory limits. Other compounds can be modeled with knowledge of that compound's retardation factor and plume extent. Details of retardation factor calculations are presented in Newsom (1985).

Model Description - Random-Walk.

The two dimensional Random Walk solute transport model developed by Prickett, Naymik, and Lonnquist (1981) was selected to simulate aquifer response to pumping. It is a finite difference model and incorporates the effects of convection, dispersion, and chemical reactions. The Random-Walk solution technique is based on the concept that dispersion in porous media is a random process. The dissolved constituents are represented as particles of mass of a given solute concentration. In the model, particle motion follows two paths through an aquifer flow system. One is along the mean flow path, and the other a random motion governed by scaled probability curves related to flow length and the longitudinal and transverse dispersivity coefficients.

The analytical version of the model used was limited to a 10 by 10 grid and a maximum of 1000 particles. This restriction may limit the accuracy of the model at the later stages of the project when few particles remain in the model and the predicted concentrations are low. When only a few particles remain in the model, the predicted concentration from the recovery well can vary significantly. The best fit line was based on early data to counter this loss of precision.

Model Calibration - Random-Walk

The grid was aligned with regional ground water flow. The regional longitudinal and transverse flow velocities were, therefore, 0.3 and 0.0 feet/day, respectively.

The contaminant source was modeled as a slug, using a circle corresponding to the location of the actual source (see Figure 1). A grid size of 25 feet by 17.5 feet was used to encompass the benzene plume. The particle mass was calculated using the predicted mass of the plume before pumping was initiated. The predicted benzene mass was calculated as the product of the average concentration and the wetted volume of the impacted area.

The values for longitudinal and transverse dispersivity were selected by history matching the size and character of the dissolved plume with the actual plume. This is a standard calibration method for the model, and should provide reasonable confidence in the prediction.

Model Description - Method of Characteristics

The second model selected for simulation of solute transport was developed by Konikow and Bredehoeft in 1978, and involved a "Method of Characteristics" solution. The two-dimensional model computes changes in concentration over time caused by convection transport, hydrodynamic dispersion, and mixing. As with other models in this study, the MOC does not account for free product.

Finite difference approximations to the ground water flow equation are solved, while simultaneously solving the solute transport equation using the method of characteristics. The contamination in this model is represented as particles of known concentration.

Model Calibration - Method of Characteristics

The grid axes were oriented along the direction of ground water flow. The water table contour was digitized onto the grid area and homogeneity was assumed for the remaining parameters. Constant head nodes were placed at the perimeter of the grid.

In this model, the contaminant source was input as a slug, using an injection well near the location of the actual source (see Figure 1). The mass was determined using the volume and log mean concentration of the actual dissolved plume before pumping. Good agreement with observed concentrations was obtained.

Model Description - Mixed Tank

The aquifer was also modeled as a continuously stirred tank (CST). This model was designed as an easy method of approximating project life when little is certain about aquifer characteristics. In this model, the recovery well is assumed to extract a representative sample from the impacted aquifer. Clean water is drawn into the contaminated portion of the aquifer and a "mixed" sample is withdrawn by the recovery well.

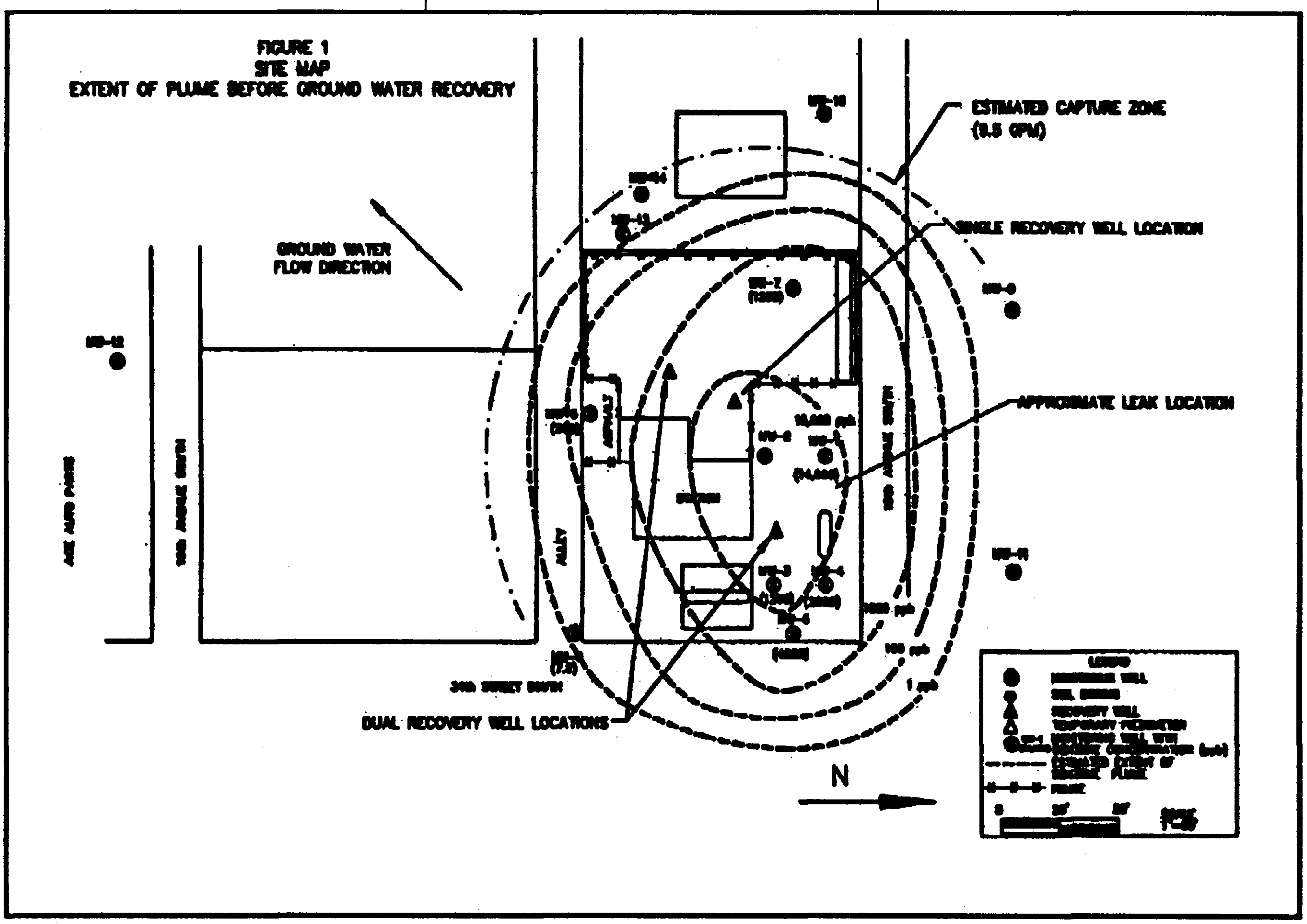

FIGURE 1
SITE MAP
EXTENT OF PLUME BEFORE GROUND WATER RECOVERY

Table 1: Model Input

Transmissivity	2930 gpd/ft
Storage Coefficient	0.2
Porosity	20%
Aquifer Thickness	40 ft
Long. Dispersivity	10 ft
Trans. Dispersivity	3 ft
Retardation Coef. (benzene)	4.4

The boundary of this model is set up as the capture area of the recovery well and assumed to be constant throughout the modeling period. The capture zone of the recovery well was determined by correlating distance drawdown data from a pumping test with the observed hydraulic gradient. With knowledge of transmissivity, hydraulic gradient and aquifer thickness, analytical solutions can also be used in this determination (Bear, 1979). In this model, the mechanism of dispersion is not accounted for. Under pumping conditions, the induced advective forces are assumed to control the plume's migration. This assumption is contingent upon complete capture of the plume by the recovery system and frequent recharge of the impacted area of the aquifer. In the case studied, the impacted area was recharged every 63 days at the modeled flowrate.

The retardation factor used in the previous two models was incorporated into this model to account for adsorption of the contamination. As with the other two models, the mixed tank model does not account for free phase product.

The first order differential equation developed for a fixed volume tank containing a known initial concentration follows:

$C_t = C_o \exp(-t\, Q/vol)$;

where:

C_t = contaminant concentration at time t (ppb)

C_o = contaminant concentration at time t = 0 (ppb)

t = time (days)

vol = wetted volume of the contaminated aquifer (total volume porosity)

Q = effective pumping rate (q/R) (gpd)

q = actual ground water extraction rate (gpd)

R = retardation factor

Model Set-up/Calibration - Mixed Tank

The initial "tank" contaminant level was estimated as the average of the benzene plume within the well's capture zone before pumping. The volume of the tank was estimated as the wetted volume of the aquifer within the capture zone of the well. The calibration process does not require dispersion of the contaminants from a known leak location over time. Rather, only the aquifer conditions before pumping is initiated are required.

The average concentration calculations were compared with samples taken from the recovery well under pumping conditions. The discrepancy between the two concentrations varied from 6% to 27%. From this result, confidence can be placed in the model's primary assumption that the well is extracting a sample representative of the overall aquifer condition.

Model Results

Two cases were studied for each of three models. The first case simulated ground water control using a single recovery well. To test the validity of the estimates, this model run was compared with actual recovery well sample data from the referenced project site. The second case simulated a dual recovery well system. The purpose of the two simulations was to illustrate the effect of these two ground water con-

Table 2: Observed and Predicted Concentrations

Observed		Method of Characteristics				Random Walk				Continuously Stirred Tank			
		1 Well		2 Wells		1 Well		2 Wells		1 Well		2 Wells	
Time years	Conc. ppb	Time years	Conc. ppb	Time years	Conc. ppb	Time years	Conc. ppb	Time years	Conc. ppb	Time years	Conc. ppb	Time years	Conc. ppb
0.01	4000	0.13	1770	0.13	1426	0.14	2231	0.14	1550	0.01	4000	0.03	3803
0.12	2800	0.19	1652	0.19	1196	0.27	1698	0.27	859	0.03	3866	0.03	3756
0.19	2000	0.27	1416	0.27	999	0.41	1353	0.41	765	0.04	3800	0.04	3697
0.29	1900	0.38	1139	0.38	699	0.55	1145	0.55	644	0.06	3704	0.05	3625
0.39	2000	0.54	842	0.54	472	0.68	711	0.68	436	0.09	3564	0.07	3537
0.46	1900	0.75	517	0.75	278	0.82	652	0.82	396	0.14	3564	0.08	3430
0.58	2400	1.06	229	1.06	140	0.97	326	0.97	342	0.21	3086	0.1	3301
0.69	1300	1.48	129	1.48	57	1.1	296	1.1	275	0.47	2231	0.16	2963
0.79	1100	2.08	51	2.08	17	1.38	257	1.38	121	0.7	1666	0.2	2748
0.92	830	2.92	17	2.92	4	1.52	119	1.52	188	1.05	1075	0.26	2502
		4.08	4	4.08	1	1.65	168	1.65	148	1.58	557	0.32	2225
		5.72	1	5.72	0	1.79	119	1.79	148	2.37	208	0.4	1922
						1.93	79	1.93	74	3.55	47	0.5	1600
						2.06	49	2.06	74	5.33	5	0.62	1272
						2.2	59	2.2	74	8	0	0.78	956
						2.47	20	2.47	54			1.22	427
						2.61	59	2.61	34			1.9	121
						3.02	30	3.02	40			2.38	51
						3.43	10	3.43	27			3.71	4
						3.57	10	3.57	40			4.64	1

trol alternatives on the overall project life.

Flow rates consistent with the aquifer characteristics were selected such that the area would not be dewatered. The flow rate for one recovery well was set at 9.5 gpm; for two recovery wells at 7.0 gpm/well.

Positioning of the recovery wells relative to the plume is shown in Figure 1. The two wells were positioned a distance apart which would allow both wells to sustain the modeled flow rates.

In each of the three models, the estimated concentration from the recovery well(s) was plotted versus time on a semi-log plot. Project closure was gauged as the point at which the best fit line of the modeled data reached 1 part per billion.

Figure 2 graphically presents the results of the models for the single recovery well case. Figures 3 through 5 illustrate the results of the dual recovery well simulation for each of the three models and, also the single well results for comparison. The mean estimated project life is 5.5 years for the first simulation. The two well system yielded a mean estimate of 4.3 years. Table 3 summarizes the project life estimates obtained by the three models. The estimated percent reduction of project life resulting from the addition of a second recovery well is also presented in this table.

Discussion - Extrapolation of Field Data

The available data from the recovery well (approximately one year), were extrapolated to intersect the X-axis of Figure 2. The intersection represents an estimated 6 year project life. The line, in this case, was extrapolated 6 times the available history data. Generally, extrapolation beyond twice the available data is not recommended. A high degree of confidence, therefore, can only be placed on the predicted concentration after an additional year of pumping. The 6 year estimate is presented for comparison only. The trend observed during the first year of operation exhibits a nearly exponential decline in benzene concentration. On sites with actual recovery data available, this method can be effectively used to approximate the project closure. Care should be taken, however, to continuously update estimates as new data become available.

Discussion - Random-Walk

The Random-Walk model has proven to be an effective method of estimating project life with a mini-

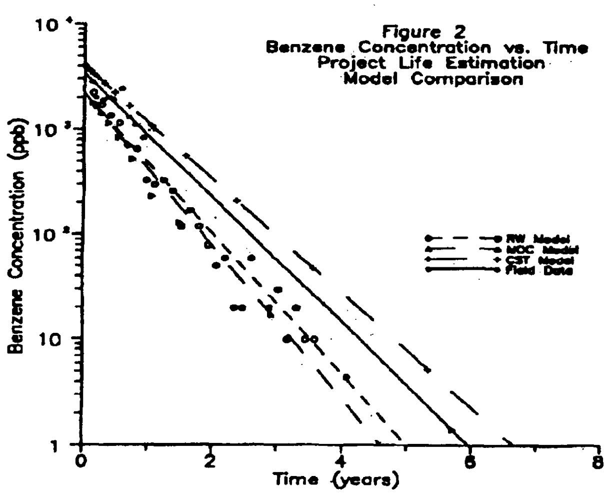

Figure 2
Benzene Concentration vs. Time
Project Life Estimation
Model Comparison

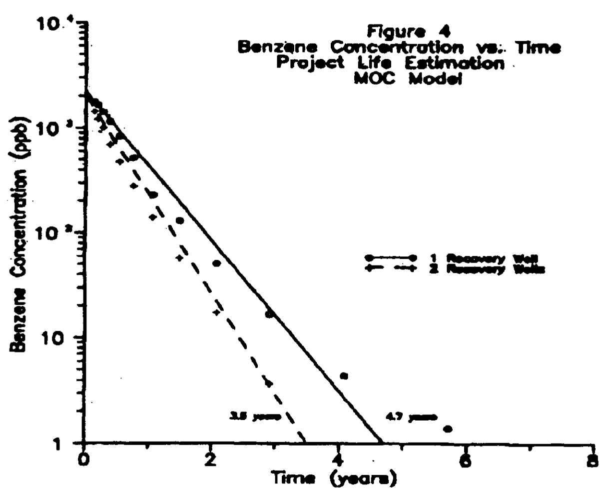

Figure 4
Benzene Concentration vs. Time
Project Life Estimation
MOC Model

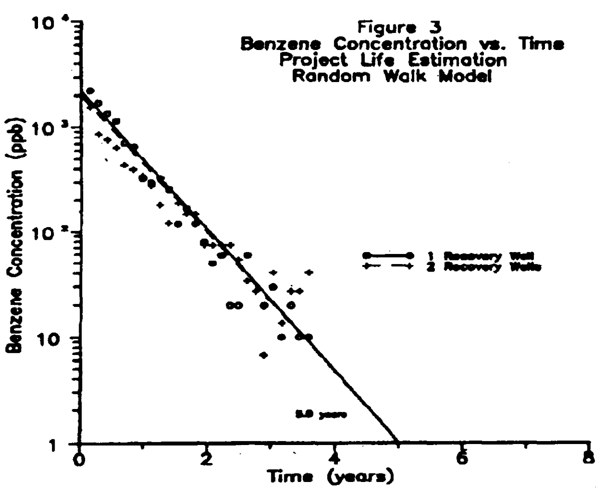

Figure 3
Benzene Concentration vs. Time
Project Life Estimation
Random Walk Model

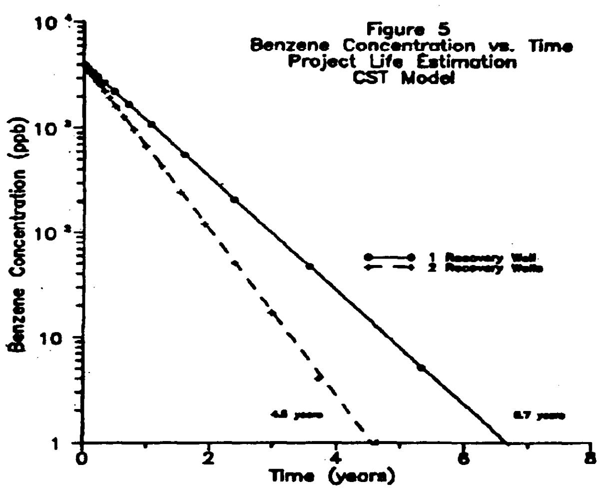

Figure 5
Benzene Concentration vs. Time
Project Life Estimation
CST Model

Table 3: Model Results

Random-Walk Model

1 Well	2 Wells	% Red
5.0 years	5.0 years	0

MOC Model

1 Well	2 Wells	% Red
4.7 years	3.5 years	26

Cont. Stirred Tank

1 Well	2 Wells	% Red
6.7 years	4.5 years	33

mum number of required input parameters. Favorable factors include ease of calibration and data entry as well as speed of execution. A limiting factor is low resolution, particularly for large areas and at low concentrations.

The project life estimated by the Random-Walk method was approximately 5 years for the single well simulation. The initial recovery well concentration predicted by this model was high relative to the other models. The concentration, however, stabilized after approximately 1 month of simulated pumping.

As shown in Figure 3, the project life estimates for 1 and 2 recovery wells using Random-Walk are not significantly different. The model suggests that the 2 well system may actually induce spreading of the plume into relatively clean areas before removing it.

Discussion - Method of Characteristics

The MOC model required significantly more time to calibrate that the other two models studied. Run time for a simulation, in addition, was longer. An advantage to this model was that head data was also simulated in addition to contaminant transport. With sufficient knowledge of aquifer and contaminant parameters, this model can provide an effective means of determining project life.

The project life estimate for the single well case determined using the MOC model is approximately 4.7 years. This prediction lies within the range shown by the other models. The output from the model represents average concentrations for the 15 by 15 feet node that contains the recovery well. These average concentrations are, therefore, lower than anticipated for the pumping well. Again, leveling off of the concentration determines the end of the project rather than the absolute level.

Unlike the Random-Walk Model, the use of dual recovery wells did predict a reduction in the project life of approximately 26% from 4.7 to 3.5 years (see Figure 4).

Discussion - Mixed Tank

The mixed Tank model was the simplest and easiest to use of the three models. The only required inputs were the initial average concentration, area and thickness of the impacted aquifer, retardation factor and an estimate of achievable flowrate.

For a single recovery well, the CST model predicted a project life of 6.7 years. In the single well case, the stirred tank model was the most conservative estimate of the three. This result was expected due to the model's disregard for recovery well placement relative to the 'hot spots' of the plume. The transport models described above take into account this geometry and, therefore, predict a larger initial decrease in contaminant level than is predicted by the tank model.

For the dual recovery well system, 4.5 years was predicted as the project life estimate. This is an improvement of approximately 33%. This model considers only flowrate, not induced dispersion of the plume toward the recovery wells. The predicted reduction in project life may be unrealistically high.

Summary

Using data available after the completed site assessment, the three models were close in their prediction of project life. The range predicted by the models were within 2 years of each other. The discrepancy in these predictions is the result of assumptions associated with each model. Each of the models closely matched the concentrations observed during the first year of remediation indicating a good degree of accuracy in the model's prediction.

For the aquifer studied, the models did not clearly indicate that a second recovery well would produce a significant decrease in the project life. This is due to the transmissive nature of the aquifer and the ability to effectively control the plume with a single well. A present worth analysis could be conducted to determine if the decreased project life resulting from the second well's operation is cost effective.

At sites with less transmissive characteristics or a greater plume expanse, the methods outlined in this report can be used in recovery alternative selection. By doing so, closure may be achieved more quickly and cost-effectively.

In conclusion, useful approximations of contaminant transport in a stressed aquifer to determine project life can be accomplished with any of the three models studied in this report. This is contingent on an understanding of the assumptions and limitations of the models. The models described in this report are all easy to use and offer relatively accurate and cost-effective results.

References

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Bear, J. 1979. Hydraulics of Groundwater, McGraw Hill.

Konikow, F. and Bredehoeft, J.D. 1978. Computer Model of Two-dimensional Solute Transport and Dispersion in Groundwater. Techniques of Water Resources Investigations Book 7 Chapter C2, USGS.

Newsom, J. M. 1985. Transport of Organic Compounds Dissolved in Ground Water. Ground Water Monitoring Review. Spring Issue.

Prickett, T. A., Naymik, T. G. and Lonnquist, C. G. 1981. A Random-Walk Transport Model for Selected Ground Water Quality Evaluations. Illinois State Water Survey.

Southwest Florida Water Management District. 1988. Ground Water Resources Availability Inventory: Pinellas County, Florida.

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Calendar

September 27, 1990. *Minnesota Environmental Health Association, 1990 Fall Education Conference.* To be held at the Duluth Entertainment Convention Center. Contact MEHA, 3819 Riverton Ave., Eagan, MN 55122.

September 27, 1990. *RCRA Corrective Action: Meeting the Requirements and Controlling the Costs.* To be held at the Stouffer Concourse Hotel in Arlington, VA. Contact Government Institutes, Inc., 966 Hungerford Dr. #24, Rockville, MD 20850. (301) 251-9250.

September 30 - October 5, 1990. *Mineral and Hazardous Waste Processing Technology Transfer Symposium.* To be held in Butte, Montana by the Montana College of Mineral Science and Technology. Contact T.S. Jordan (406) 496-4112.

October 1 - 3, 1990. *Theory and Practice of Ground Water Monitoring and Sampling - Designed for Newly Practicing Professionals.* To be held at the Ramada Renaissance Hotel in Long Beach, California by NWWA.

October 1 - 3, 1990. *Principles of Subsurface Contaminant Fate and Transport Modeling.* To be held at the Ramada Renaissance Hotel in Long Beach, California by NWWA.

October 1 - 3, 1990. *Agricultural Chemicals and Ground Water: An Examination of Important Issues.* To be held in Long Beach, California by NWWA.

October 4, 1990. *Environmental Site Assessments One-Day Course.* To be held at the Ramada Renaissance Hotel in Long Beach, California by NWWA.

October 11 -13, 1990. *International Drilling Federation's Spotlight 90.* To be held in Indianapolis, Indiana. Contact IDF, 3008 Milwood Ave., Columbia, SC 29205. (800) 445-8629.

October 15 - 19, 1990. *Multiphase Organic Transport Modeling with Emphasis on Pollution by Hydrocarbons.* To be held by the IGWMC in Indianapolis, Indiana.

October 22 - 26, 1990. *The Role of Environmental Audits and site Assessments in Property Transfers.* To be held in Atlanta, Georgia. Contact Education Extension - R, Georgia Institute of Technology, Atlanta, GA 30332-0385. (404) 894-2400 or (800) 325-5007.

October 23 - 25, 1990. *A Comprehensive Approach to Development and Protection of Ground Water Supplies.* To be held at the Sheraton Palace Hotel in San Francisco, California by NWWA.

October 23 - 25, 1990. *Designing In Situ Waste Recovery Systems.* To be held at the Sheraton Palace Hotel in San Francisco, California by NWWA.

October 24 - 25, 1990. *Applied Drilling Engineering for Rotary and Auger Methods (for ground water-related investigations).* To be held at the Sheraton Palace Hotel in San Francisco, California by NWWA.

October 29 - November 1, 1990. GSA Annual Meeting. To be held at the Dallas, Texas Convention Center. Contact GSA Meetings Department at P.O. Box 9140 Boulder, CO, 80301; (303)447-2020.

October 29 - November 2, 1990. *Safety at Hazardous Materials Sites: A Hands-On Workshop.* To be held at the Westchester County Public Safety Training Center, Valhalla, New York, by NWWA.

October 30 - 31, 1990. *23rd Annual Water Resources Conference.* To be held at the University of Minnesota, St. Paul, MN. Contact Bev Ringsak, Professional Development and Conference Services 335 Nolte Center, University of Minnesota, 315 Pillsbury Dr. S.E. Minneapolis, MN 55455 (612)625-6689.

October 31 - November 2, 1990. *Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection and Restoration.* To be held in Houston, Texas by NWWA.

November 1 - 2, 1990. *Managing Hazardous Substances at Federal Facilities.* To be held in Denver, CO. Contact Executive Enterprises, Inc., (800) 831-8333.

November 4 - 9, 1990. *26th Annual AWRA Conference - "The Science of Water Resources: 1990 and Beyond" and " Symposium - Transferring Models to Users".*To be held at the Hyatt Regency in Denver, Colorado. Contact AWRA, 5410 Grosvenor Lane, Suite 220, Bethesda, Maryland 20814-2192. (301) 493-8600.

November 5 - 9, 1990. MODFLOW for Simulation of Ground Water Flow and Advective Trasport. To be held at Bally's Las Vegas in Las Vegas, Nevada by NWWA.

November 6 - 8, 1990. *Critical Issues in Underground Storage Tank Management - Focuses on new EPA requirements.* To be held at Bally's Las Vegas in Las Vegas, Nevada by NWWA.

November 6 - 8, 1990. *Theory and Application of Vadose Zone Monitoring, Sampling, and Remediation.* To be held at Bally's Las Vegas in Las Vegas, Nevada by NWWA.

November 7 - 9, 1990. *Practical Environmental Law.* To be held at the Hotel del Coronado in Coronado CA. Contact Federal Publications, Inc., 1120 20th street NW, Washington DC 20036. (202) 337-7000.

November 8 - 9, 1990. *Pesticides in the Next Decade: The Challenge Ahead.* To be held in Richmond, VA. Contact Diana L. Weigman, Asst. Director of Research/Admin., Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, 617 N. Main Street, Blacksburg, VA 24060-3397.

November 9, 1990. *Legal Implications of Environmental Site Assessments.* To be held at Bally's Las Vegas in Las Vegas, Nevada by NWWA.

November 12 -14, 1990. *Effective Techniques For Contaminated Groundwater Treatment.* To be held at the Wisconsin Center in Madision, Wisconsin, by University of Wisconsin-Madison/Extension, Dept. of Engineering Professional Development, 432 North Lake Street, Madison, Wisconsin 53706. (800) 462-0876.

November 13 - 15, 1990. *Environmental Regulation.* To be held in St. Louis, MO. Contact Executive Enterprises, Inc., (800) 831-8333.

November 14 - 16, 1990. *Compehensive Ground Water Contamination Management: a short course for environmental professionals in industry.* To be held at the Orlando Marriott in Orlando, Florida, by NWWA.

November 27 - 30, 1990. *Practical Karst Hydrogeology with Emphasis on Ground Water Monitoring.* To be held in Cave City, Kentucky by NWWA.

December 3 - 5, 1990. *Principles of Ground Water Hydrology.* To be held at the Columbus Marriott North, Columbus Ohio by NWWA.

December 3 - 5, 1990. *Fundamentals of Ground Water and Well Technology.* To be held at the Marriott Inn North, Columbus Ohio by NWWA.

December 3 - 5, 1990. *Environmental Regulation.* To be held in Denver, CO. Contact Executive Enterprises, Inc., (800) 831-8333.

December 3 - 7, 1990. *Safety at Hazardous Materials Sites: A hands-on Workshop.* To be held at the Orlando Marriott in Orlando, Florida, by NWWA.

December 5 - 7, 1990. *Goundwater Management District Association - 1990 Annual Conference.* To be held in Colorado Springs, CO. Contact G.M.D.A. 1990 Annual Confernce, P. O. Box 126, Wahoo, NE 68066.

January 13 - 18, 1991. *IBM PC Applications in Ground Water Pollution and Hydrology: A Hands-on Short Course.* To be held in San Francisco, California by NWWA.

February 6 - 8, 1991. *Iowa Well Water Association Convention.* To be held in Des Moines, Iowa. Contact Dennis Scheider, IWWA Executive Director, 900 Des Moines, Ste. 200, Des Moines, IA 50309. (515) 266-2189.

March 19 - 21, 1991. *In Situ and On-Site Bioreclamation, An International Symposium.* To be held in San Diego, CA. Contact Battelle Inc., Phillip Wells, (800) 783-6338.

May 13 - 16, 1991. *Outdoor Action Conference/ Expo.* To be held in Las Vegas, Nevada by NWWA.

For information about meetings and seminars to be held by the NWWA, contact NWWA at 6375 Riverside Drive, Dublin, Ohio 43017 (614) 761-1711, Telex 241302.

For information about Short Courses held by the International Ground Water Modeling Center (IGWMC), contact the IGWMC, Holcomb Research Institute, Butler University, Indianapolis, IN 46208 (317) 283-9458.

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USGS Ground Water Training Activities

The U.S. Geological Survey (USGS) conducts training activities at virtually all organizational levels, encompassing field and district offices (more than 200), the four regional offices and the National Training Center, located in Denver, Colorado.

Instructors of courses range from supervisors and district technical specialists to subject-matter authorities. During 1989, 46 courses were taught at the USGS's National Training Center, involving more than 900 students. Of that number 52 were scientists from other federal agencies, and 86 were from state or local water agencies with whom the USGS has cooperative agreements.

The National Training Center catalog lists five ground water subject areas: general, geophysics, hydrology, geochemistry, and modeling. Not all courses may be offered in a fiscal year. Scheduling of National Training Center courses is continuously updated, and the calendar may be accessed through USGS's computer network. The local USGS contact for these programs is Kurt Gunard in St. Paul at (612) 229-2624.

Wellhead Protection Area Model Available

The WHPA code is a modular, semi-analytical, ground water flow model developed for the USEPA, Office of Ground Water Protection, and designed to assist state and local technical staff with the task of Wellhead Protection Area (WHPS) delineation. The model is designed to PC use.

The model consists of four independent, semi-analytical modules that may be used to identify the areal extent of ground water contribution to one or multiple pumping wells. One module is a general particle tracking program that may be used as a post-processor for two-dimensional, numerical models of ground water flow. One module incorporates a Monte Carlo approach to investigate the effects of uncertain input parameters on capture zones. Multiple pumping and injection wells may be present and barrier or stream boundary conditions may be investigated.

To obtain a copy of the code and user's guide contact IGWMC, Holcomb Research Institute, Butler University, 4600 Sunset Ave., Indianapolis, IN 46208; (317) 283-9458.

A $50 cost for the code includes a diskette copy of the code, the user's guide and assistance with code installation. IGWMC is not responsible for providing technical assistance.EPA is hosting six workshops to provide "hands-on" training in use of the WHPA code. Although attendance at these workshops is limited, there may still be available slots in some locations.

Little Booklet Saves a Lot

Water Efficiency for Your Home--Products and Advice Which Save Water, Energy, and Money, published by the Rocky Mountain Institute, is available to help individuals improve the water and energy efficiency of their own homes and save money in the process.

The booklet is designed for homeowners and tenants but its ideas can also be applied on a larger scale.

The booklet tells homeowners how to save about a third or more of the water they use simply by:

- replacing inefficient water-wasting fixtures with efficient state-of-the-art products; and
- redesigning landscapes with colorful, durable, native, low water-using plants.

Copies of the booklet are available for $5 from: Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass, Colorado 81654-9199, (303)

Newsletter Advertising Policy

Advertising space is available in this newsletter to businesses and organizations. Display ads (4 issues = 1 year) are charged by fractional page:

Size	*inches*	*Annual Rate*
business card	*3.5x2.4*	*$50*
quarter page	*3.5x5*	*$90*
half page	*7x5*	*$170*
full page	*7x10*	*$320*

Copy should be camera-ready.

The Editor has final determination on the acceptance of materials submitted. There are no commissions on ads. Advertising copy must be received by the publication deadlines: February 15, May 15, August 15, or November 15. The ad should be accompanied by a purchase order or a check. Checks should be payable to the Minnesota Ground Water Association. All materials should be sent to the Editor:

Jan Falteisek
Editor, MGWA Newsletter
DNR - Division of Waters
500 Lafayette Road
St. Paul, MN 55155-4032

Braun Environmental Laboratories Analytical Excellence Award

Braun Environmental Laboratories, Inc. was presented the 3M 1989 Analytical Excellence Award from 3M Environmental Laboratory. The award is presented annually to laboratories whose work in the environmental field is rated outstanding in the areas of organization, communication, responsiveness, and analytical quality.

Braun is the first laboratory in Minnesota to receive the award and was one of only four laboratories nationwide to receive the award this year.

(From a Braun News Release)

MODEL VALIDATION: Bringing Three Views Together

by Paul van der Heijde, Director of The International Ground Water Modeling Center - Indianapolis

These days most of us agree that protecting our water resources for future use and remediating past mistakes require our undivided attention and strong commitment. The choices we need to make bear with them significant financial consequences.

Those who are responsible for political and administrative decisions should base those decisions on reliable information and thorough analysis. This requires proper integration and use of technically and scientifically sound data collection, information processing, and interpretation methods.

As computer codes are essential building blocks of modeling-based analysis, it follows that before these codes are used as planning and decision-support tools, their credentials must be reliably established. In software engineering, that process is called validation. Its objective is to determine how well a code meets the design criteria, which include efficiency, accuracy, stability, and robustness. Implicitly, it is assumed that at the end of such a determination, either the validity of the software is established, or the software has failed to meet the criteria.

This interpretation, applied to ground water simulation software, has resulted in much confusion. A major reason for this confusion is that model validation is being interpreted differently by each of three different constituencies:

- Researchers and scientists who need model validation to confirm the scientific proof of their theories.

- Practicing professionals who need to know the performance of a model in terms of its applicability to specific problems, engineering solutions, and the like, in terms of accuracy and efficiency.

- Water resources managers and agency administrators who need to know how reliable the model's predictions are in order to make sound management decisions.

All three groups look for field validation as the ultimate answer. The problem here is that field validation means something different to each group:

- For the researcher, a theory cannot be proven, only disproven. Field validation is a way to reduce or eliminate levels of doubt among peers in terms of the correctness and completeness of the model's formulation. This group looks for systems that can be used to validate their models. Systems that cannot be simulated by the model under scrutiny should be considered in other ways, such as through the application of other models, or by the initiation of new research.

- For practitioners, the question is: Does the model work for my kind of problem, or if not, is there a model that will work? If there is, and that model does the job, how do I use it correctly?

- The decision maker is much less interested in the validity of the model than in the reliability of the total modeling process. This reliability is influenced by the quality of the data, the concepts and methods used in the data interpretation, and the approaches taken to the evaluation of management scenarios, including modeling, sensitivity analysis, and uncertainty analysis.

The model as a tool is only a part of the validity issue. In fact, if the model chosen has been well peer-reviewed and tested, the model itself should not be the key issue; management's focus should be on the other elements of the modeling exercise and on the integration of all elements of information gathering and analysis in the decision process.

To resolve these different approaches to field validation we need to build consensus on several issues:

ON THE MODELS - We need to develop and accept:

- standard procedures for peer review, testing, and quality assurance.

- standard procedures for characterizing model applicability.

- professional design of our modeling software; i.e., the introduction of software engineering concepts that are user-oriented. It should be noted that user friendliness and transparency in software design contribute significantly to user confidence.

ON MODEL USERS - We should:

- promote training of potential users and disseminate new information quickly and widely.

- develop informative and error-making-preventative/resistant software.

ON THE APPLICATION - We should:

- require extensive QA.

- expose all applications to peer review.

- perform parallel modeling of important problems by independent modeling groups, with successive consensus-building review sessions.

- promote the use of complete modeling procedures at all sites, including standardized sensitivity, error, and uncertainty analysis aimed at providing insight into reliability, uncertainty, and prediction as part of decision-support risk analysis.

(Reprinted with permission from the IGWMC Ground Water Modeling Newsletter, Spring 1990, Vol VIII, No.4)

Call For Papers

Environmental Site Assessments: Case Studies and Strategies

Sponsors: National Water Well Association and Association of Ground Water Scientists and Engineers

July 29-31, 1991.

The assocaiation of Ground Water Scientists and Engineers is organizing its second Environmental Site Assessments Conference at the Fawcett Center for Tomorrow - Ohio State University Campus in Columbus, Ohio. Presentations by environmental lawyers, lenders, and real estate personnel will compliment the technical discussions. The meeting will concentrate on case studies and strategies, providing environmental scientists with practical informantion that will improve their ability to conduct site assessments.

This notice serves as the call for papers for persons interested in participating in the meeting. Environmental scientists, lawyers, and lending institution and real estate personnel are invited to submit abstracts. Case studies and/or plans-of-action dealing with the following topics will be considered:

- Pricing considerations
- Levels of investigative effort
- The impact of property size on the site assessment process
- Proposal preparation
- The process of initiating a site assessment
- Scope of environmental investigations
- Ground water monitoring wells
- Responses to environmental problems discovered
- Written record
- The non-scientific side of site assessments

A limited number of contributed papers will be accepted for presentation at the conference. Professionals interested in submitting an abstract should contact NWWA at (614) 761-1711 for instructions.

Deadline for receipt of abstracts and biographical sketches: January 11, 1991. Deadline for receipt of completed manuscripts: April 19, 1991.

1991 GSA Meeting: North-Central Section

Sponsor: Geological Society of America.

April 18-19, 1991.

The North-Central Section of the GSA will be holding its Spring meeting at the University of Toledo-Seagate Campus in Toledo, Ohio. The abstract deadline for this conference is December 12, 1990. Completed abstracts may be submitted to D.J. Stierman, Department of Geology, University of Toledo, Toledo, OH 43606; (419) 537-

Changes

James S. Aiken has left Barr Engineering to attend the Geology Graduate Program at the University of Wisconsin-Madison to pursue a Masters degree in geology.

Linda Ho Gilson has accepted the position of Hydrogeologist at Malcolm Pirnie, Inc. She was formerly an Environmental Geologist at Twin City Testing.

Greg Kimball was promoted to Hydrogeology Department Manager at Delta Environmental Consultants, Inc.

David J. Little has accepted the position of Environmental Assessment Group manager at Nova Environmental Services, Inc. He was formerly at GME Consultants.

Marty Moran was promoted to Hydrogeology Department Manager at Delta Environmental Consultants, Inc.

Gene Murray was promoted to Director of Geoscience at Delta Environmental Consultants, Inc.

Barry D. O'Flanagan was promoted to Environmental Science Division Manager at Delta Environmental Consultants, Inc.

Minnesota Valley Testing Laboratories, Inc. has moved its Corporate Offices as of June 11 1990. Their new street address is: 1126 North Front Street, New Ulm, MN 56073. The mailing address remains: P.O. Box 249, New Ulm, MN 56073-0249. For questions call (800) 782-3557.

Booklet on Nitrates Available

Nitrates & Groundwater: A Public Health Concern is a 16-page booklet which describes how nitrates affect human health, both in infants and adults, and offers preventative strategies and specific guidelines for protection of drinking water supplies.

In an easy-to-understand, nontechnical Q-and-A format, the brochure answers such commonly asked questions as:

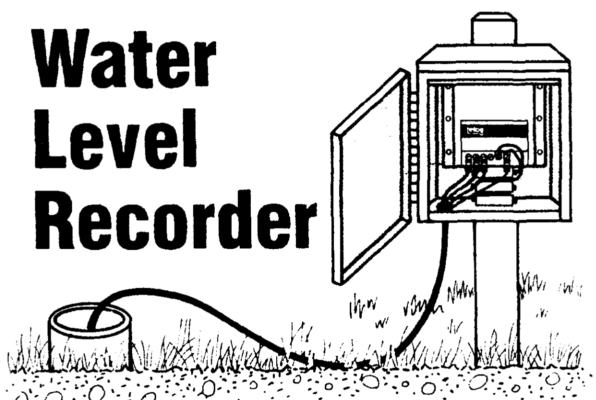
- what are nitrates?;
- how do they get into ground water?;
- how much nitrate is too much nitrate?;
- how does nitrate affect human health?;
- what is methemoglobinemia?;
- can nitrates be removed from water?;
- can nitrates in well water cause cancer?; and
- what can you do if your well has high levels of nitrates?

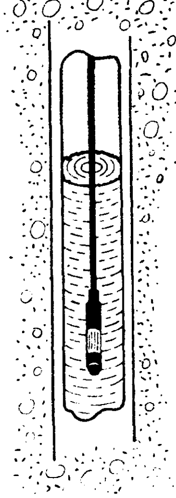
To receive a free copy of *Nitrates & Groundwater: A Public Health Concern*, write to the Publications Department, Freshwater Foundation, 2500 Shadywood Rd., Box 90, Navarre, MN 55392, or call (612) 471-8407. Additional copies are $.50 each with discounts available on orders of 500 or more.

Course in Contaminant Ground WaterTransport open to practicing hydrologists.

Dr. Pfannkuch will be teaching GEO 8617, Transport Phenomena in Natural Porous Media this fall quarter, on Wednesdays, 3:35-5:30 p.m.

This is a graduate course but practicing professionals and undergraduates can register through Extension using GEO 5980 (Sec 1) after having spoken with Dr. Pfannkuch (624-1620). The course starts September 26





Fall Meeting

Environmental Risks - Contrasting Perceptions

November 14, 1990

Thunderbird Hotel

Bloomington, Minnesota

8:30 a.m. to 3:30 p.m.

Lunch Provided
Conference Fee $40
Just complete the form below and mail to: Minnesota Ground Water Association, PO Box 65362, St. Paul, MN 55165

- -

Environmental Risks - Contrasting Perceptions. November 14, 1990 Thunderbird Hotel, Bloomington

Registration Form

Name ______________________________
Title ______________________________
Affiliation ______________________________
Mailing Address ______________________________
____
City, State, Zip Code ______________________________
Telephone Number ______________________________
Make your $40 checks payable to the Minnesota Ground Water Association. Receipts will be provided, if requested, upon your arrival at the Hotel.
Will you need a receipt in addition to your cancelled check? ______________________________

Join the Minnesota Ground Water Association!

If you are reading this newsletter second-hand, we'd like to take this opportunity to invite you to become a member of **MGWA** for 1991. Annual dues are currently still $10 for professional members and $5 for students.

Just complete the form below and mail to: Minnesota Ground Water Association, PO Box 65362, St. Paul, MN 55165

- -

Name ______________________________
Affiliation ______________________________
Mailing Address ______________________________
City, State, Zip Code ______________________________
Telephone Number ______________________________
Address for Directory Listing ______________________________
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Mark your Calendar Now for this Upcoming Meeting:

November 14, 1990: Environmental Risks - Contrasting Perceptions. Featuring Dr. Jay Lehr, NWWA, 8:30 am - 3:30 pm at the Thunderbird Hotel, Bloomington.

Minnesota Ground Water Association
P. O. Box 65362
St. Paul, MN 55165