1990 C.V. THEIS AWARD

Citation

Mr. Chairman, Ladies and Gentlemen:

Shlomo Neuman is most appropriate as the 1990 recipient of the C.V. Theis Award. Theis made vital contributions to quantifying the physics of ground water flow and applying these to both the theoretical and practical aspects of subsurface hydrology. Similarly, Professor Neuman has, for the past 25 years, made equally vital theoretical contributions as well as practical applications of theory. As Robert Smith, the 1991 Linsley awardee stated, "good theory is good practice," Shlomo Neuman epitomizes this maxim. His studies have increased our understanding of the effects of aquitards on regional flow systems, the applications of finite-element theory to ground water flow, hydraulic testing in unconfined aquifers, fractured-rock hydrogeology, hydraulic scaling factors, and stochastic analysis of hydrogeologic systems. One cannot work for long in subsurface hydrology before encountering one of Shlomo's original and significant contributions.

Shlomo Neuman was born in Czechoslovakia. He received a B.S. from Hebrew University of Jerusalem and his M.S. and Ph.D. in engineering science at the University of California at Berkeley. He is currently a Regent's Professor at the University of Arizona where he has been an effective teacher and inspiring mentor. He has received numerous honors and recognitions, but none, I believe, more appropriate than the C.V. Theis Award. Just as the Theis Award honors our 1990 awardee, Shlomo Neuman equally honors C.V. Theis and the field of groundwater hydrology.

It gives me great pleasure to present the C.V. Theis Award to Shlomo P. Neuman.

John M. Sharp, Jr.

Response

Mr. Chairman, Colleagues and Friends:

I am greatly honored and privileged to be the recipient of the 1990 C.V. Theis Award of the American Institute of Hydrology. The work of C.V. Theis has helped lay the foundations for modern ground-water hydrology, a discipline and a profession the American Institute of Hydrology guards and promotes. Among ground-water hydrologists the name of C.V. Theis is considered second only to that of Henri Darcy, who in the mid-nineteenth century discovered the constitutive law on which the work of Theis and much of the discipline are based. Prior to the publication of Theis' landmark paper in 1935, quantitative ground-water hydrology was based on Darcy's law and the principle of mass conservation, applied without recognizing the ability of subsurface materials to release water from internal storage below the water table. Theis' genius was to recognize that wells in artesian aquifers derive their water from internal storage due to compaction of the aquifer material and expansion of the water as its pressure declines, just as heat is released from a solid when its temperature goes down. The implication is that ground water potentials dissipate gradually with time, rather than equilibrating instantaneously, a phenomenon described a decade earlier by Karl Terzaghi in connection with the consolidation of soils under stress, but applied to artesian aquifers for the first time by Theis. A similar application to oil reservoirs has been proposed independently several years after Theis by petroleum engineers who only now are beginning to credit Theis for what to them has been known simply as the exponential integral, due in large measure to the efforts and power of persuasion we all admire in our colleague and my former mentor, Paul Witherspoon. C.V. Theis' contribution has had an immense and lasting impact on ground water theory and practice, including my own work, and I am therefore extremely happy and proud to be the recipient of an award which honors his name. I thank the American Institute of Hydrology for the honor and for the important role that it plays in promoting the spirit of C.V. Theis among ground-water professionals.

C.V. Theis' idea made possible the intensive development during the nineteen fifties, sixties and seventies of diverse analytical solutions for problems of flow to a well in a homogeneous aquifer. Many of these solutions mimic real world behavior with amazing fidelity. A number of them have been developed into practical tools for the determination of well, aquifer, and aquitard hydraulic parameters by means of pumping and injection tests. The relative ease with which some such tests can be performed and interpreted has facilitated their adoption as favorite and standard tools by ground-water practitioners; the recent development of computerized packages for the design and interpretation of hydraulic tests will soon render many additional solutions of practical use to the hydrologic community. This has brought about a rapid accumulation of field data about the hydraulic properties of aquifers and aquitards which however revealed that such properties generally vary from one test location to another and with direction during a given test. Field evidence has been mounting that the subsurface is less uniform and isotropic than had been assumed by those who developed the very solutions which helped bring about the evidence. Experience has shown that whereas analytical solutions which treat aquifers and aquitards as homogeneous isotropic units can often reproduce test drawdown or recovery data quite well, the ability of such solutions to predict future drawdowns or recoveries generally deteriorate, often quite rapidly, with the length of the forecast. Many hydrologists have reached the conclusion that whereas analytical solutions may be appropriate for the hydraulic characterization of aquifers and aquitards on local scales, they may be less adequate for hydrologic analyses on larger scales or for long-term hydrologic forecasts. In their search for more sophisticated and reliable tools they turned first to electric and other physical analogues, later to numerical methods and the computer.

Computers now dominate every facet of our professional and private lives to such an extent that to ignore or avoid them is futile. Their potential ability to help the hydrologist appears limitless: Computers can help translate, transfer, organize, store, compare, analyze, and display huge amounts of data in ways that would otherwise have to be much more selective; computers can solve mathematical problems of immense complexity, numerically or symbolically, that would otherwise have to be greatly simplified. Yet selecting the most relevant information to describe a hydrologic phenomenon or process, and developing or relying on the simplest theory which captures their essential features, have always been and should remain the marks of a competent hydrologist. While the computer need not in principle rob the hydrologist of his/her ability to synthesize and analyze, it often appears to do so in practice. There is a tendency among young hydrologists to require answers from the computer for problems that a competent hydrologist should be able to resolve with not much more than paper and pencil. For example, many problems for which answers are routinely sought from finite difference or finite element models could be solved by the superposition of available analytical expressions, or by the development of relatively simple alternative expressions, that could then be computerized if necessary for numerical evaluation. What one might loose by simplifying reality one might gain many fold by capturing the essence of the hydrologic phenomenon or process, thereby gaining invaluable insight that is otherwise often lost. This is what I learned from C.V. Theis and those who followed in his footsteps: this is what I learned from my own professional experience; and this is what I consider to be C.V. Theis' chief legacy to future generations of hydrologists. We in academia who have taken upon ourselves to educate the young generation, and the American Institute of Hydrology which certifies their professionalism, have a duty to impart this legacy to out students and to foster it among those whom we empower to practice the art and science of ground-water hydrology.

Having said that the ability to select and simplify are among the most important attributes of a competent hydrologist, I wish to qualify this by noting that good hydrologic practice does not imply ignoring real-world complexities or shunning theories and models which attempt to explain them. Without a theoretical understanding of such complexities, or the ability to analyze them, one may lack the ability to make rational decisions about what to ignore and what to consider. For example, it is generally believed that dispersion is less important than advection in the analysis of contaminant transport. Though dispersion may appear to be relatively small in laboratory and local-scale field tracer experiments, there are compelling theoretical reasons to make it much larger when attempting to predict the movement of subsurface contaminants over distances that exceed such scales. The reason is that, in the usual absence of detailed knowledge about the spatial and temporal variations in ground-water velocity on scales of relevance, the continuity equation for the solute becomes stochastic. This stochastic equation can be averaged to yield a deterministic equation which contains an advective and a dispersive flux component, yet the dependent variable is no longer the concentration but merely its estimate. This estimate of the concentration is advected not with the actual ground-water velocity but with its estimate. It is dispersed not just by molecular diffusion and hydrodynamic mixing on sub-sampling scales but also, and more so, by the manner in which missing information about the velocities is autocorrelated in space-time. The greater is our ignorance of these velocities, the less detailed must be our description of the advective velocity field; what we don't know about the latter we must build into the dispersive term to preserve mass balance. If and when we learn more about this field, we may be justified transferring such newly gained information from the dispersive to the advective term, reducing the former and rendering the latter more detailed. The very structure of the deterministic transport equation is thus seen to be strongly dependent on the quantity and quality of the information at our disposal. This is not how we have been interpreting and applying this equation in the past; our current approach is overly simplistic and needs to be reevaluated.

I shall not bore you with the technical details but our approach to flow suffers from the same lack of appreciation for the roles of scale and information content in modelling as does our approach to transport and requires reevaluation.

Rather than viewing ground-water flow and transport models as reflections of real hydrologic behavior, we must view them as tools to estimate such behavior on the basis of available information on scales compatible with those of real data. The quantities entering into such models must not be metaphysical but related in a clear and unambiguous manner to what can actually be measured and sampled. We all know that when hydraulic parameters such as those determined by the method of C.V. Theis are assigned to the grid blocks of a numerical flow model, the latter often fails to reproduce observed water level behavior with acceptable accuracy. The common approach is to modify the grid block values via model calibration till, at times, the results bear little resemblance to the original pumping test data. Should such models be considered reliable predictors of hydrologic behavior outside the regime under which they have been calibrated? Unfortunately, experience suggests that the answer must often be negative: Most models must be continuously recalibrated to fit newly acquired data. The incompatibility between real field and artificial grid block parameters is an artifact of our traditional inattention to issues of scale and information content in hydrogeologic analysis. I propose that we now have the conceptual tools, and the computer technology, to start correcting this situation and thereby place our methods of analysis on a firmer footing. The computer is neither a threat to, nor a replacement for, sound hydrologic theory and judgement; it is a tool that can help us apply and exercise the latter efficiently as we prepare to face the complex water supply and environmental issues of the twenty first century. The computer may mislead rather than help us if we neglect to understand the theory; if we minimize the importance of data support for our analysis; if we overlook issues of scale and uncertainty in the interplay between data and models; if we sacrifice one set of data for the sake of a better model fit with another set; or if we read more into the output from our models than is theoretically justified by its structure and by the data on which it is based. Let us strive together to avoid such pitfalls while building to the fullest on the intellectual legacy of C.V. Theis in the context of recent theoretical advances and modern technology.

Thank you all very much.

Shlomo P. Neuman