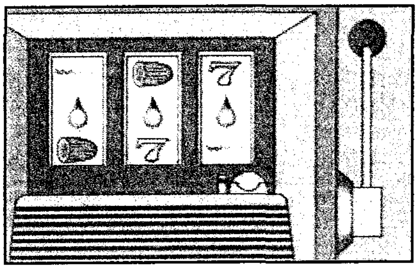
BULLETIN

Fall 2004 | "American Institute of Hydrology, the Society for Registered/Certified Hydrologists" | Volume 22, Issue 3

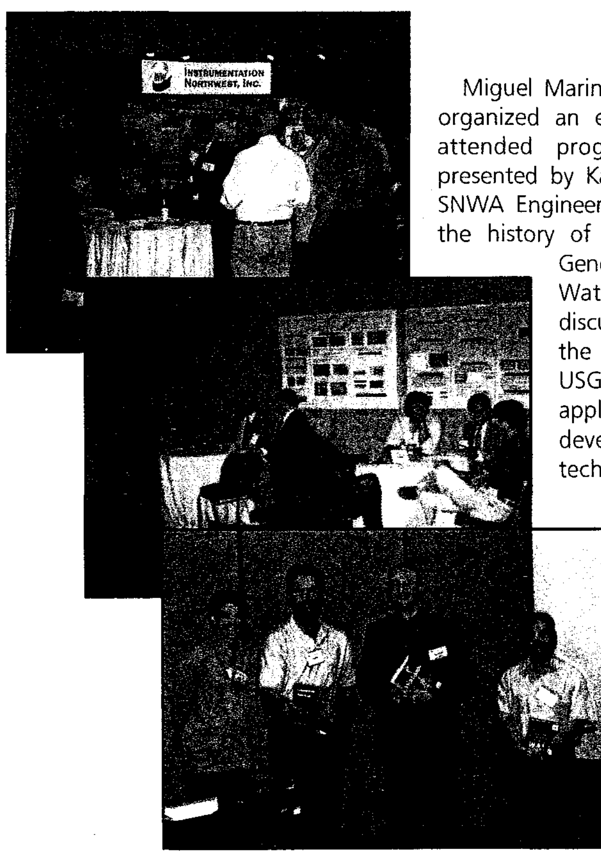


VIVA, Las Vegas
A Summary of the 2004 Annual Meeting

Integrated Water Resources Management
October 17 - 20, 2004

The 2004 AIH Annual Meeting at the Alexis Resort and Hotel, in Las Vegas, Nevada was the first time in over 21 years that we held a meeting that was not planned and arranged by Helen Klose. She left us to do it all ourselves. Although it was not one of our best attended meetings, those that did attend were a part of an excellent technical program and social time. The Organizing Committee, headed up by Emitt Witt and Doug Glysson decided to forego the large banquets and have more time to socialize and network at breaks and receptions. The poster presentations, exhibitors and vendors were setup in the same area as the breaks and receptions. This allowed for maximum contact with the attendees and as a result the exhibitors and vendors were very pleased to be a part of the meeting. On Monday night we were entertained by magician, Gary Norsigian, who thoroughly impressed us all with his slight-of-hand and showmanship. He especially impressed our President Pat Leahy, who was intent on finding out the magician's secrets.

In This Issue



Technical Program

Miguel Marino, the Technical Program Chairman, organized an excellent set of papers into a well attended program. Keynote addresses were presented by Kay Brother, Deputy General Manger, SNWA Engineering and Operations, who spoke on the history of the Colorado River; Doug Miller, General Counsel for the Central Arizona Water Conservation District who discussed the National Ramifications of the Miccosukee Lawsuit and Keven Roth, USGS, who discussed the benefits and applications of the National Map Program developed by the USGS. All of the technical papers will be assembled, peered reviewed, and published in the next volume of the HS&T Journal. The student papers were just as well presented as the others and will be reviewed for publication as well. John Wiley Book Company donated several text books that were awarded to the students for their participation in the program.

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COMPARISON OF THREE COMPUTER MODELS OF UNSATURATED FLOW

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ABSTRACT

Comparison of computer program SEEP/W, a finite element model of two-dimensional seepage, to two other soil-water flow models is presented. Comparison models used are the U.S. Army, Cold Regions Research and Engineering Laboratory (CRREL), FROST2B finite element model, and a one-dimensional nodal domain model of a vertical soil column. The first obvious test is to compare models of a steady-state problem involving a simple homogenous embankment of pervious silty soils on an impervious foundation. The next test was to examine SEEP/W applied to a sharp wetting front problem. While the finite element method works well for many cases, particularly for cases where changes are gradual, the finite element method may not work well for sharp changes such as a wetting front advance. The comparisons in part verify SEEP/W results.

Key words: unsaturated flow, finite element method, groundwater models

INTRODUCTION

The explosion of computer-based technology applied to a host of engineering applications has made a significant impact on how engineers analyze and design. It is literally possible to find software that does about everything we do. In this case we are interested in the advance of the phreatic surface through a levee that failed during a severe flood event that did not overtop the levee. To analyze this problem we used a software package called "SEEP/W" which is marketed by GEO-Slope International of Calgary, Canada. Although the users manual for this software contains some verification, we conducted our own verification. The purpose of this brief technical note is to present two examples of verification using our own models (Guymon, et al., 1993 and Hromadka, 1986) which had been prepared for the U.S. Army Corps of Engineers. The first and most obvious test was a two-dimensional steady-state levee configuration, and the second test was for the rapid advance of a wetting front since the finite element method which SEEP/W is based upon sometimes models these problems inaccurately.

BRIEF DESCRIPTION OF SEEP/W

This is a dynamic two-dimensional model of saturated/ unsaturated flow in vertical slices. The model is based on the finite-element method (for example Guymon, 1994). The model accommodates a variety of boundary conditions and heterogeneous soils. It is flexible in using a wide range of parameters. The model accommodates a variable grid space and several finite element types are available.

The model is imbedded in a Windows format and there is excellent problem setup capability as well as capability to review results.

BRIEF DESCRIPTION OF COMPARISON MODELS

The comparison models are both based on the finite element method embedded in a nodal domain scheme depending upon the weighting factor used in the capacitance matrix (Hromadka, 1986) and both are dynamic. One model which we call "UNSATO3" (Guymon, et al. 1993) solves the dynamic movement of water in a vertical soil column and accommodates a variety of boundary conditions and parameters. The other model which we call "FROST2B" (Hromadka 1986) is a two-dimensional dynamic model based on linear triangular elements. It too accommodates a variety of boundary conditions and parameters. Both models (Guymon, et al., 1993 and Hromadka, 1986) have been extensively tested against simplistic analytical solutions, field data, and instrumented laboratory column data.

RESULTS

The most obvious test is to determine if a steady-state problem can be modeled correctly. To do this, a simple homogeneous embankment of pervious silty soils on an impervious foundation was modeled. The embankment geometry is shown in Figure 1. A reservoir water table was imposed on the left side and exactly the same parameters were used in SEEP/W and FROST2B. Soil water parameters are represented by Gardner's relationship (Guymon, 1994) as follows:

$$\theta(\psi) = \theta_S / [A_W (\psi)^{\alpha} + 1], \psi \leq 0$$

$$K(\psi) = K_S / [A_R (\psi)^{\beta} + 1], \psi \leq 0$$

Where θ_S is porosity, K_S is saturated hydraulic conductivity, ψ is pore water pressure, and A_W, A_R, α and β are best fit parameters. Table 1 lists the parameters used. Note that SEEP/W uses a table of θ and K versus ψ which was determined from the above equations.

Both models used right angle triangular elements 2 feet on each side. The results are shown in Figure 1 for pressure heads. If the results are superimposed on each other, the results are essentially identical. Notice both models simulate the expected seepage surface on the downstream toe.

The next test was to determine if SEEP/W could correctly model a sharp wetting front. While the finite element method works well for many cases, particularly for cases where changes are gradual, the finite element method may not work well for sharp changes such as a wetting front advance. The degree that this may be a problem depends somewhat on the skill of the person who prepared the model code. Additionally, there may be convergence and oscillation problems when modeling a dynamic unsaturated flow.

The UNSATO3 model, in addition to being a finite element method, is based upon the nodal domain method (for example

Guymon, 1994 and Hromadka and Guymon, 1981) which allows one to choose a system matrix weighting parameter to simulate say integrated finite differences which can handle sharp wetting front problems accurately. This model and FROST2B were compared to the SEEP/W model for a vertical soil column of permeable silts. For each model, the exact same boundary conditions and parameters were used. In this case soil characteristics (i.e. pore pressures related to water contents) and the hydraulic conductivity as a function of pore pressures had to be the same for each model (see Table 1).

Figure 2 depicts the model discretization, boundary and initial conditions. Figures 3 and 4 show the simulated results at 12-hours. Figure 3 depicts pore pressures and Figure 4 depicts water contents. For both the SEEP/W and FROST2B results the wetting front (which is moving upward) is in advance of the UNSATO3 model which we regard as more accurate. Notice the UNSATO3 results yield a somewhat sharper wetting front. Despite this discrepancy we regard the SEEP/W results as satisfactory. None of the models exhibited convergence or oscillation problems.

CONCLUSIONS

An example of comparisons of SEEP/W results to two other models is presented. The comparisons in part verify SEEP/W results.

SEEP/W is an easy to use model with many attractive features. In our case, we found that the learning curve to use SEEP/W was relatively short. It is recommended that new users of this model should first start with a simple problem and geometries before tackling more complex problems.

APPENDIX I - REFERENCES

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LIST OF TABLES

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2004 Awards Program

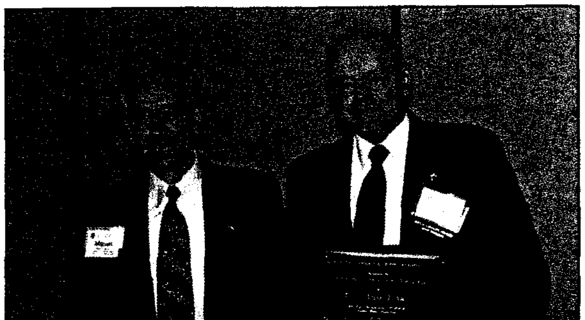
On Tuesday at Lunch, AIH presented the Founder's, C.V. Theis and R.K.Linsley Awards to outstanding recipients.

Miguel Marino, Bill Klose and Belinda Klose

The **Founder's Award** was presented posthumously to Helen Klose, former Office Manager of AIH for over 20 years. Her children Bill and Belinda accepted the award. Also, in attendance were Helen's grandchildren, Collin, Nathan and Nicholas, her daughter-in-law, Tarii and Hiedi Burkhorst, a friend.

Yoram Eckstein, Jozsef Toth and Miguel Marino

The **C.V. Theis Award** was given to Jozsef Toth, Alberta, Canada for his pioneering work in Groundwater Hydrology. Yorham Eckstein gave the citation for Professor Toth.



Miguel Marino and Tom Haan

The **R.K. Linsley Award** was presented to Tom Haan, Stillwater, Oklahoma, Dr. Haan is a Past President of AIH, and is honored for his long and dedicated service in the field of surface water hydrology. Stephen Burgess, the 2003 Linsley Award winner, presented the citation for Dr. Haan's award.

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Conceptual Model of Water and Dissolved Salts Movement Through Portland Cement Concrete

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Theodore V. Hromadka, Professor
United States Military Academy, West Point, New York
& Professor Emeritus, California State University, Fullerton

THE PROBLEM

A frequently occurring topic in hydrology is the movement of soil moisture through concrete slabs and into the interior of the structure. The problem is the potential (or lack of) movement of water through Portland cement (PC) concrete slabs that may range in thickness from 3 to 5 inches. Frequently, the source of water generally is underlying groundwater that is naturally occurring, or may be provided by man as irrigation seepage or other factors. These waters have dissolved salts, particularly the sulfate ion, which is occasionally observed on floor surfaces or has damaged floor coverings such as carpet and caused tiles to loosen. When there is moisture transport, the underlying mechanism may be described by the theory of unsaturated flow in porous media.

PC CONCRETE

PC concrete is a man-made stone consisting of aggregate, Portland cement (a limestone powder), and water to initiate the chemical reaction to cause the cement to harden and bind the aggregate together into a solid matrix. Aggregate is usually sand to gravel sizes. Various admixtures are sometimes added to the wet mix to promote desired properties such as early curing or enhanced workability.

Generally, PC concrete will reach about 95 percent of its maximum strength within about 5 days. Concrete is strongest in compression and its compressive strength as well as tensile strength is enhanced by steel reinforcement.

The construction process for installing PC concrete as building slabs and foundations is to truck in ready mixed concrete to the site and pour or pump the concrete into forms to form a pad or slab on compacted soil which may have a thin gravel layer between the slab and soil. Prior to this, plastic sheeting is often laid down to form a barrier to upward water movement after the concrete is cured. Additionally, wire reinforcing screen is often laid down on approximately one inch thick blocks to keep the screen elevated in the mixture. In modern practice, it is common to vibrate the wet concrete to minimize voids.

Sometimes workers can be seen punching holes in the plastic sheeting before the ready mix arrives. This is done for two reasons. One is to allow excess water in the ready mix to drain faster and promote faster setup and curing. The other is that excess water causes what is called "crazy cracks" to form during working and curing, making exposed surfaces somewhat unattractive.

PC CONCRETE AS A POROUS MEDIA

In nature, when a cementing agent, aggregate, water, and time are suitable, an indurated sedimentary stone is formed. Fine uniform silts are called "siltstone" while uniform sands are called "sandstone." When a mixture of sizes ranging to gravel or larger sizes are present the stone is called "conglomerate." PC concrete is basically a man-made conglomerate.

Almost all of these stones are a porous media with a finite porosity and hydraulic conductivity. For example, Domenico and Schwartz (1990) indicate that ranges of values for saturated hydraulic conductivity for siltstones, sandstones, and limestone may be from 10^{-11} to 10^{-9} m/s.

During its curing phase, PC concrete has small pores that are caused by entrapped air and water. If the workmen are not careful, some pores can be quite large (cm sized). Some of the pores are interconnected so that the hardened porous concrete has a hydraulic conductivity which may be in the range of those listed for sandstone.

Porous PC concrete will allow unsaturated as well as saturated flow to develop in the presence of a water source. The presence of cracks perpendicular to a water source will inhibit unsaturated flow, and cracks of any orientation will enhance saturated flow.

THE HORIZONTAL PC CONCRETE SLAB

The potential movement of moisture and transport of dissolved minerals through a horizontal PC concrete slab is envisioned as a predominantly one-dimensional process. It is recognized that at the edges of the slab where the building wall footings are, there is potentially a two-dimensional flow and transport process.

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Journal of Hydrological Science and Technology 2006 Call for Papers

The Journal for Hydrological Science and Technology is the peer reviewed technical publication of research and practical studies on Hydrologic and related topics. The Journal was initiated by the founders of AIH in 1985 to publish regular and brief technical papers that communicate ideas, findings, methods, techniques or summaries of interesting projects or investigations. The Journal accepts papers dealing with all aspects of Hydrology and Water Resources, including water pollution and hazardous waste issues. The Executive Committee recently appointed Dr. Ted Hromadka as the Editor of the Journal and B.J. Seaburn will continue as the AIH's Publication Manager. Contact BJ if you want to submit a paper or if you would like to serve as a reviewer at **bjesterstudio@aol.com**. Please indicate the type of papers you would like to review. If you know of others that may have a paper that can be published, please forward this information to them or invite them to visit our web site at **www.aihydro.org**.

The submission deadline for accepted papers in Volume 22 is **September 15, 2006**. The 2006 Journal Volume 22 will be printed and distributed by **November 30, 2006**.

Should you have a paper for consideration, please submit a 250 word abstract of your paper to:

American Institute of Hydrology
300 Village Green Circle, Suite 201
Smyrna, GA 30080.

Where there is cracking, saturated flow, if it can develop, is enhanced. However, for saturated flow to develop there must be a hydraulic head such that there is an energy potential greater than atmospheric.

What is more common is to have a water source near the bottom of the slab; i.e., a high perched water table at or below the slab bottom. Another common situation is poorly drained clays may be present and have enough moisture to provide a water source. Water sources may be drainage from landscape irrigation or rainfall infiltration which has moved downslope under the slab. Consequently, unsaturated flow is the dominant process of interest.

A CONCEPTUAL MODEL OF WATER MOVEMENT

A one-dimensional vertical PC concrete column is assumed with vertical upward movement of water and dissolved salts. At the bottom there are moist soils and at the top it is much dryer. Continuous wetting is assumed; i.e., the lower boundary condition stays moist and does not dry out. As a result hysteresis is not a factor. **Figure 1** depicts the physical situation. The total hydraulic head (units of length since the gravitational constant has been divided into each term) is denoted by h where $h = z + p$, z is the elevation head and p is the pore pressure head which is less than zero for unsaturated conditions.

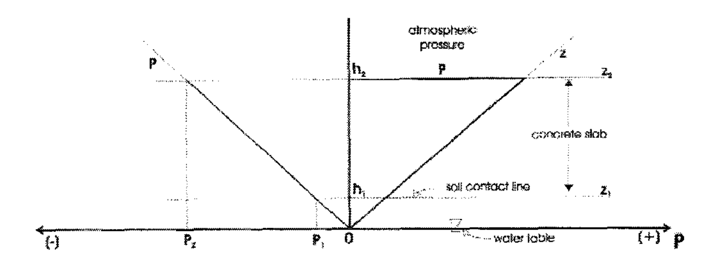

Figure 1. Conceptual System: z=elevation; p=pressure.

For unsaturated conditions p is a function of water content, w (units of vol/vol) as shown in the hypothetical retention curve depicted in **Figure 2**. Numerous measurements, however, have been made on porous media so that there is some general concept of how such a relationship might look for PC concrete. If the top of the column is relatively dry, $p2$ is many atmospheres negative while at the bottom of the column, $p1$ is negative but near zero.

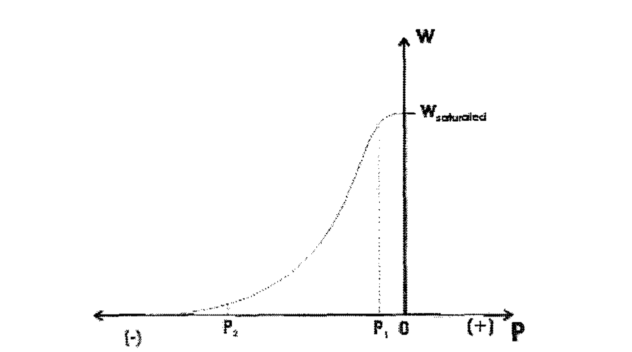

Figure 2. Conceptual Relationship Between Water Content (w) and Pore Pressure (P) for an Unsaturated Soil Media.

Consequently, there is a very large gradient upward; i.e.

$$\textbf{grad } h = (h2 - h1)/(z2 - z1) \qquad (1)$$

Guymon (1994) discusses the origin of the forces that make up p.

To determine the moisture flux, v, upward, Darcy's law is used; i.e.

$$v = - \mathbf{K}(w).\textbf{grad } h \qquad (2)$$

where $\mathbf{K}(w)$ is the hydraulic conductivity which is a function of water content or pore water pressure, i. e., $\mathbf{K}(p)$ (Guymon,1994). For most fine grained soils the hydraulic conductivity function changes considerably (over log-cycles) with changes in water content, w.

A complete model applicable to the situation conceptualized here is given by Guymon (1994):

$$\partial(\mathbf{K}(p)\partial h/\partial z)/\partial z = (\partial w/\partial p)(\partial h/\partial t) \qquad (3)$$

Boundary conditions are discussed above. Initial conditions would be a uniform but small water content throughout the column. (An application of this conceptual model including phase change is found in Kim and Heydinger, 2002).

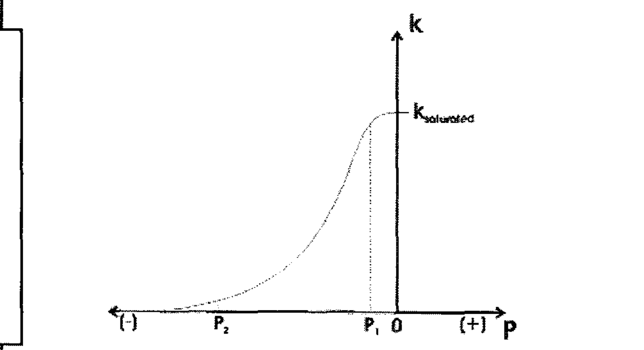

Figure 3. Conceptual Relationship of Hydraulic Conductivity (k) to Pore Pressure (P) for an Unsaturated Soil Media.

Figure 4 shows the wetting process in the one-dimensional PC concrete column. Upward moving wetting fronts are a result of a wet condition at the bottom of the column and drier conditions at the column top. Very strong upward pressure gradients dominate the process. After a long time, moisture flux is in equilibrium and quasi-steady-state is achieved and Equation 3 reduces to Equation 2. Moisture is continuously supplied by the underlying soil, is transported through the column, and exits the surface as evaporation where it may condense in floor coverings. This is similar perhaps to a desert situation where there may be a water table below the surface. It is well known in Boy Scout lore that a desert survival technique is to place a sheet of plastic or tarp over the surface and arrange it so its underside will drain into a container. During the night groundwater moisture collects on the bottom side of the covering and drains into the container.

To make a very rough calculation of how much moisture might be transported, assume a vertical PC concrete column 10 cm tall. At the bottom assume $p1$ equal zero and assume at the top $p2$ equal -1,000 to -10,000 cm of water. Assume the log-averaged hydraulic conductivity is 10^{-11} to 10^{-13} m/s. From Equation 2, the hypothetical velocity flux ranges from about 0.01 mm/day to 10 mm/day.

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Conceptual Model _- continued from Page 6_

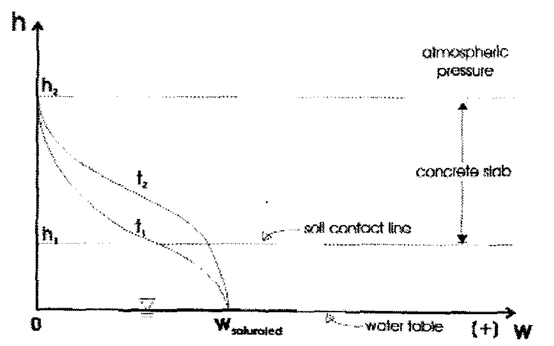

Figure 4. Conceptual Wetting Curves through a Concrete Slab for Various Times $t_2 > t_1$.

A CONCEPTUAL MODEL OF DISSOLVED SALT TRANSPORT

An underlying soil water is envisioned that has dissolved salts but the solution is dilute. We are particularly interested in the sulfate ion which apparently is a major component of salts deposited on floor surfaces. How does the sulfate get there?

The dissolved sulfate is being transported with the upward moving water. It is well known that sulfate in dilute solutions is miscible with water and that it does not react with most porous media (Hillel, 1980a,b). Consequently, the appropriate mass transport model is (Guymon, 1994):

$$\bullet C/\bullet t + v_s \bullet C/\bullet z = \bullet(D \bullet C/\bullet z)/\bullet z \quad (4)$$

where C is the concentration, t is time, z is the vertical coordinate, v_s is the seepage velocity (v/w), and $\mathbf{D}$ is the dispersion coefficient. At the bottom of the column the sulfate transport boundary condition is approximated by some constant concentration. The appropriate top boundary condition is open to question. If it were $\bullet C/\bullet z = 0$, we could obtain an analytical solution to Equation 4. For an initial condition, one might assume the sulfate to be a uniform concentration of zero. The solution is not sensitive to the initial condition over a long time period.

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