DISAPPEARING PRACTICE OPPORTUNITIES: WHY ARE OWNERS AND ENGINEERS TAKING INCREASED RISKS? WHAT CAN BE DONE TO COUNTER THIS THREAT?

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ABSTRACT

Over the last 25 years 96% of the ABET-accredited civil engineering programs in this country decided to omit engineering geology as a required course. This trend emanated from surveys of practicing engineers asked to rank the importance of courses they had taken in college. For most institutions engineering geology has become an elective course taught by geotechnical engineers, not geologists.

This shift in educational emphasis is one of several factors that have decreased valuation of engineering geology and its contribution to successful engineering projects. During this same interim there has been an increasing trend by owners to ask engineers to accept increased risks, especially in regards to geotechnical issues, which often take years to manifest themselves. Project managers have also been encouraged to shave site characterization costs to be more competitive. The result has been an increased use of "conservative" assumptions about site conditions, to compensate for the lack of subsurface borings, lab tests and geologic input. This practice can prove dangerous in geologic terrains that are complex.

It is not clear what can be done to reverse this trend, short of the engineering profession experiencing some high-visibility ground failures. Lapses in site characterization are usually ascribed to "unforeseeable" site conditions, which could not "reasonably" have been detected beforehand. But, it could also be argued that the absence of a competent exploration program by experienced individuals leads to erroneous assumptions about the variability of site conditions. The geotechnical profession will become increasingly litigious and performance-based building codes are being adopted nationwide. At some future time the importance of engineering geologic input will reemerge and minimal standards for site characterization may become codified or insurance rates elevated to re-capture the increased casualty losses.

RECOGNITION OF ENGINEERING GEOLOGY

Recognition by civil engineers of the need for engineering geologic input on most civil engineering projects evolved during the first half of the 20th Century, mostly in association with construction of transportation and water resources infrastructure. During those formative years a handful of geology professors availed themselves as external consultants on a number of high visibility projects, mostly dealing with dams. These included W. O. Crosby at MIT and his son Irving B. Crosby, Charles P. Berkey at Columbia, Kirk Bryan at Harvard, Heinrich Ries at Cornell, Chester K. Wentworth at Washington University, Bailey Willis at Stanford, Andrew Lawson and George Louderback at Cal Berkeley and Leslie Ransome and John Buwalda at Cal Tech (Kiersch, 1991; 2001). Reis wrote the earliest American text on engineering geology in 1914, on the heels of horrific slope stability problems experienced during excavation of the Panama Canal, between 1905-14 (MacDonald, 1915), which led to the first National Academy of Sciences publication dealing with geologic hazards (NAS, 1924).

The impact of site geology on civil works projects reached a crescendo with a series of high-visibility dam failures that shook the civil engineering community between 1928-38. Most of which were either newly completed or under construction: St. Francis Dam near Los Angeles, CA in March 1928; Table Rock Cove Dam near Greenville, SC in May 1928; Pleasant Valley Dam near Price, Utah in May 1928, Lafayette Dam near Oakland, CA in September 1928; Virgin Gorge rockfill dam near St. George, UT in July 1929; cancellation of the San Gabriel Dam during construction (which would have been the world's largest) near Azusa, CA in November 1929; Alexander Dam in Kauai, Hawaii in March 1930; LaFruta Dam near Corpus Christi, TX in November 1930; the Saluda Dam (second largest earthfill dam in the world) near Columbia, SC in February 1930; Castlewood Dam near Denver, CO in August 1933; and the Belle Fourche Dam near Belle Fourche, SD in September 1933. While these events were occurring Professors Bryan (1929a; 1929b), Berkey (1929), Terzaghi (1929) and Wentworth (1929) authored model documents defining the role of engineering geologists in civil works projects.

Despite these setbacks in public confidence, the US Bureau of Reclamation and Corps of Engineers continued to design and construct increasingly larger structures. Between 1933-40 the U.S. Corps of Engineers built the largest earthfill structure in the world near Fort Peck, Montana on the Missouri River. When nearing completion in September 1938 the upstream shell of the dam liquefied, spreading 5.2 million cubic yards of material into the reservoir. This project involved a state-of-the-art engineering agency and a prestigious panel of consultants. The dam failures of the 1928-38 decade were all ascribed to foundation problems involving settlement, slope stability and hydraulic piping. These experiences pointed out the need for properly characterizing foundation conditions before design, geologic mapping of conditions exposed in excavations during construction, and astute attention to any changed conditions detected thereby. It was a lesson to be learned repeatedly by successive generations of engineers.

ADOPTION OF ENGINERING GEOLOGY IN THE CIVIL ENGINEERING CURRICULEM

The person most responsible for ushering engineering geology into the American civil engineering curriculum was Karl Terzaghi (1883-1963). Terzaghi (1925) had written the first text on soil mechanics in 1925 while teaching at Robert College in Istanbul. Soon after the book appeared he was invited to at MIT as a visiting professor to help them solve the mysteries surrounding ground settlements occurring on the MIT campus and introduce the American civil engineering community to soil mechanics. While lecturing at MIT he co-authored the text Ingenieurgeologie (Engineering Geology) with K. A. Redlich and R. Kampe, professors at Prague's technical institute (Redlich, Terzaghi and Kampe, 1929). In late 1929 he accepted a professorship at the Technical University at Vienna. In the fall of 1938 he immigrated to Harvard University where he was named Lecturer in Engineering Geology, a title held till July 1946, when he was named Professor of the Practice of Civil Engineering.

Terzaghi's influence on American civil engineering was nothing short of profound. As a young man, Terzaghi studied geology and geomorphology in Germany after receiving his undergraduate degree in general engineering in Graz (Goodman, 1999). From then on he perceived projects from a geologic perspective and his assertions and opinions came to carry enormous weight: he had received ASCE's highest recognition, the Norman Medal, for pioneering research and publications in 1930, 1942 and 1946, more than any other engineer in ASCE's history (he added his 4^{th} Norman Medal in 1955). A handful of eminent American civil engineers dared to duel with Terzaghi in ASCE Transactions discussions, a decision they usually regretted later in their careers.

The model program for civil engineering in the 1940s was at Harvard and Terzaghi taught a course in engineering geology in the civil engineering department between 1938-1957. This became the model for other civil engineering programs after the Second World War, with most schools tapping their geology departments to teach an engineering geology or geology for engineers course. During the first generation of classroom instruction within engineering schools, the most commonly employed texts were: *Engineering Geology* by Ries and Watson (1931), *Geology and Engineering* by Legget (1939), *Application of Geology to Engineering Practice* by Paige (1950) and *Principles of Engineering Geology and Geotechnics* by Krynine and Judd (1957).

The Engineers Council for Professional Development was established as the accreditation body for engineering programs in 1932. In the early 1950s the model programs for soil mechanics and foundation engineering were located at Harvard, MIT, Illinois and Cornell. All incorporated course in engineering geology. In the 1940s ECPD recommended that every civil engineering undergraduate receive at least one basic course in soil mechanics and foundation engineering. By the mid-1950s they began recommending a course in engineering geology as well. By 1975 approximately 77% of the ECPD-accredited civil engineering programs in the United States required their students to take at least one course in engineering geology. As a sub-discipline of civil engineering, engineering geology had become a fundamental part of the American civil engineer's educational pedigree.

It naturally followed that engineering geology became firmly established within most governmental engineering organizations as well. The U.S. Corps of Engineers, U.S. Bureau of Reclamation began retaining engineering geology consultants in the late 1920s and by the late 1930s they began hiring their own staff geologists (Burwell and Roberts, 1950). By the late 1950s most state transportation agencies also employed their own geologists.

QUALIFICATIONS-BASED SECTION

During the Second World War the U.S. Corps of Engineers began using a selection process for civilian consultants that emphasized technical expertise rather than price, because they were constructing many critical facilities, including infrastructure for the Manhattan Project (Fine and Remington, 1972). After the war the Corps continued this selection practice and it was eventually adopted by the General Services Administration as well. It was not until October, 1972 that the Brooks Act (Public Law 92-582) codified Qualifications Based Selection (QBS), which established the procurement process by which architectural and engineering services are selected for design contracts with federal agencies. In the QBS process contracts for engineering services are negotiated on the basis of demonstrated competence and qualification for the type of professional services required at a fair and reasonable price. Under QBS procurement procedures, price quotations were not to be considered in the selection process. QBS was enthusiastically supported by every professional engineering society in the United States. The Brooks Act required that seven basic steps be undertaken in selecting consultants, requiring ranking of submitting firms derived from their statements of qualifications, work experience and interviews. Once ranked, contract negotiations would precede, beginning with the top-ranked firm. 35 of the 50 states subsequently adopted their own "Mini- Brooks Acts, mandating QBS in procurement of engineering services.

A weakness of the Brooks Act was that it only addressed architectural and engineering services, which required professional licensure to practice in all 50 states by 1972. However, if the federal government solicited work of a nature not requiring professional licensure, such as geology, then they were not bound to use QBS in selecting consultants! Since geology and allied sciences did not require professional registration in all states, the newly-created Environmental Protection Agency (EPA) never implemented QBS. EPA cleverly stated that licensed professional engineers were not the *only* personnel needed to investigate geoenvironmental hazards, so QBS procedures could be bypassed in favor of selecting firms based on minimum bids instead. This created a situation whereby federal agencies were required to use QBS procedures to hire someone to design a sidewalk, but price bidding could be used to retain a firm to design a remediation plan for a hazardous waste site, which, if not remediated properly, could wind up poisoning thousands of people!

Legal challenges to the Brooks Act occurred often over the succeeding decades, as government bean counters sought to reduce costs, assuming architectural and engineering services were akin to manufactured parts, which the government routinely procures via rigid low bid selection. The Federal Streamlining Acquisitions Act was introduced in 1993. Among other things, it sought to revoke QBS selection procedures mandated by the Brooks Act, arguing that other unlicensed professionals could perform much of the work currently burdened by the more expensive QBS procedures. The 75,000 word act was subsequently passed by Congress in 1994, but lobbying by engineers and architects precluded dissolution of the Brooks Act for A/E services, but not for anyone practicing in the geosciences.

THE GEOENVIRONMENTAL REVOLUTION

In 1976 Congress passed the Resource Conservation and Recovery Act (RCRA). This act was the first serious attempt to address the management of solid and hazardous waste. The Environmental Protection Agency was empowered to regulate hazardous waste from the cradle to the grave while solid waste was to be regulated by the individual states. A major outgrowth of RCRA was the emerging field of geoenvironmental consulting, which grew almost exponentially between 1982-94, to service every landfill operator in the country, large and small.

In 1984 the RCRA was amended to extend government authority over siting, construction and monitoring of approximately two million underground storage tanks, mostly from gasoline service stations. The 1984 amendments created an unprecedented surge in geoenvironmental work, known colloquially as “yank-a-tank” consultations. Engineering geologists formed the bulk of the manpower expended to take on this new challenge and thousands of small to medium sized consulting firms soon appeared to perform the necessary work. A decade later the yank-a-tank splurge was over and there were thousands of unemployed geologists looking for work. The larger geoenvironmental firms who worked on landfills and for large industrial clients were able to survive.

BID SHOPPING

The EPA’s example of soliciting cost-based proposals has gradually spread to other agencies and across the width and breadth of the private sector. Geoscientists are not legally accorded the privilege of Qualifications Based Selection (QBS) at the federal level, nor in many states. The federal Bureau of Reclamation and Corps of Engineers have used QBS procedures in selecting all of their external consultants, even though not required by law. If QBS procedures are not in place, bid shopping is technically legal. This represents the single greatest disadvantage of practicing in the geosciences rather than pure engineering.

Bid shopping for engineering and geology services has become commonplace over the past 20 years. This forces professional services firms to cut their direct and indirect expenses to remain competitive and it encourages governmental agencies to use amoral practices, such as “leaking” the quotes of competitor’s to the firm they really want to retain. For geotechnical consultants, competitive bidding is a dangerous practice because it tends to encourage shaving of site characterization costs, which are a major line item in most proposals, and a work category that is seldom profitable. As a consequence of these market forces, most projects no longer receive the number of borings and subsurface samples that typified the era between 1950-80, when modern building and grading codes were developed.

REMOVAL OF ENGINEERING GEOLOGY FROM THE CE CURRICULEM

Between 1975-2000 the requirement for engineering geology was inauspiciously removed from the required civil engineering curriculum. In 1980 the Accreditation Board for Engineering and Technology (ABET) superseded ECPD as the accreditation body for engineering curricula. ABET soon embarked upon a program in cooperation with the American Society of Civil Engineers (ASCE) which polled practicing engineers to rank the relative importance of various coursework they had received to their everyday practice. Practicing civil engineers ranked engineering geology lower than other civil engineering courses, especially structural engineering courses. This should not have surprised anyone because only about 9% of civil engineering graduates find employment in geotechnical engineering, while slightly less than 40% use structures-related coursework in their everyday practice. Geotechnical aspects of civil engineering are usually performed by external consultants. ABET used these results of these polls to recommend "modernizing" the civil engineering curricula to phase out what it perceived to be outmoded courses and replace them with more relevant subject matter, especially offerings which emphasized computer methods. Today only 4% of the accredited civil engineering programs require their undergraduates to take a course in engineering geology. During the same interim (1975-2000) we have seen geology curriculums begin to phase out summer field geology courses and related field work because these courses are expensive to offer, remove professors from duties that generate external research support and are no considered career-enhancing.

SHIFTS IN RESEARCH EMPHASIS

When engineering geology faculty voiced their objections to the censure of their courses they were usually informed that geology is really a "sub-discipline" of geotechnical engineering, and that geotechnical practitioners would be expected to take engineering geology as an elective course. Between 1975-2000 the majority of faculty engaged in teaching engineering geology, geomorphology and field geology courses were not replaced when they retired. In many civil engineering programs students interested in taking geology coursework were simply diverted to take physical geology courses or geology for engineers, taught within the geology department. At the few institutions where engineering geology is still offered in the civil engineering department, it is usually taught by geotechnical engineering professors, not by engineering geologists.

The bottom line in this shift away from field programs is several fold. During the 1980s the educational emphasis shifted towards geoenvironmental work, and course offerings in geohydrology suddenly took center-stage, along with commensurate externally-sponsored research. A second more important factor involves research trends. Over the past quarter century research emphasis has shifted away from large engineering infrastructure like water resources and transportation to planetary and geoenvironmental challenges, for which there appears to be less emphasis on the marriage between engineering and geology. More bluntly stated, engineering geology represents a small minority of those engaged in lobbying for research dollars; so small, that it has virtually erased from the academic scene. Today major universities write announcements for faculty positions emphasizing whatever research niches the National Science Foundation happen to be funding at present. Many of the announcements sound similar, regardless of the school's size or reputation. Like the private sector, the academic scene has become increasingly competitive. What everyone wants is dollars.

ENGINEERING GEOLOGY IS CONTINUUING TO EVOLVE

The past 70 years saw the introduction of engineering geology in the formal civil engineering curriculum and its rescission, 25 to 40 years later. During this same interim civil engineering infrastructure evolved to provide water, utilities, sanitation, waste facilities and transportation networks that sustain our society. The role of engineering geology in geohydrology and geoenvironmental work remains integral to site characterization, but has gradually become less valued by geotechnical engineering organizations. This trend can be appreciated by reviewing the attendance statistics for sectional and annual meetings of AEG over the past 27 years. One of the first perks engineering companies withdrew following corporate takeovers was professional society activities.

Today, many of the smaller geotechnical firms ignore site-specific geologic input; simply referencing geologic maps and publications that may be outdated. A great many people have come to believe that the surficial geology of the conterminous United States has long since been mapped, its mysteries unraveled, and published for all to see. They do not see the need for any further study or re-examination of the underlying geology, it isn't perceived as being "cost-effective". That society as a whole shares this point of view has been demonstrated in the costly cuts suffered by the U.S. Geological Survey by mandates of Congress in the mid-1990s.

These commonly-held perceptions about the stagnancy of geology are fraught with problems. During the past 25 years a virtually revolution in geologic understanding of Earth surface processes has evolved, similar in scope to that brought about by the discovery of plate tectonics in the 1960s and 70s. These break-troughs include: discovery of the source of the Cretaceous-Tertiary boundary; the role of cataclysmic events, such as meteor impacts, paleofloods and tsunamis in shaping much of the earth's surface; the introduction of sequence stratigraphy to explain cycles of deposition, exploding the myth of linear (straight line) stratigraphy practiced by geotechnical engineers; the art of constructing balanced structural geologic cross sections, which have revealed the existence of previously unrecognized blind thrust faults across areas subjected to crustal compression; space-based sensor platforms which allow economical access to unlimited aerial photo imagery; the disappearance of stereopair photos from use in mapping; Global Positional System-equipped electronic field mapping techniques; and the emergence of Geographical Information Systems and computerized databases to collate data from a myriad of sources, to be overlaid and compared. The academic training an engineering geologist receives today is completely different from the techniques taught a few decades ago to those who compiled the geologic maps and products in everyday use across the United States! The end users are just too naive to understand the shortcomings of the geology products they use in deference to retaining a real geologist to help sort out and identify new information from the outdated.

CORPORATE TAKE-OVERS

During the economic recovery of the mid to late1980s geotechnical and geoenvironmental firms found themselves in a shifting marketplace. Many of the geoenvironmental firms began offering construction management services as a turnkey service tailored to meet their client's site clean up and restoration needs. During this same interim geotechnical firms found themselves in an increasingly competitive marketplace, due in large part to the proliferation of personal computers (PCs). PCs allowed individual engineers to start up their own businesses with almost no overhead expense. This created an increasingly competitive marketplace.

For many mainstream geotechnical firms "restructuring" became the byline phrase. Firms began to tighten their belts, deleting professional society activities and continuing education benefits. These cuts were followed by cutting out other less productive portions of the business, such as soil testing labs, analytical labs and acquisition of background reference materials. Health and retirements benefits also underwent an almost yearly restructuring due to increasing premiums. The shortfalls created by these cutbacks were compensated by using contract labs and contract employees: individuals who are paid hourly wages without benefits, overtime, vacation and retirement or tax withholding. An alternative means to reducing overhead was to engage in corporate take-overs. In this business model, a firm with trained managers would purchase small to medium sized consulting firms in other marketplaces who had a proven book of business. By placing all of these offices under one flag one could, in effect, streamline their services. In this way one of the firm's offices would handle testing, another drilling and so on. Various specialists, such as engineering geologists, could be parceled out to different job sites at different offices without paying consultant wages and overhead.

EMERGENCE OF CONTRACT EMPLOYEES AND SOLE PROPRIETORS

As the glut of geoenvironmental work begun in the 1980s evaporated a decade later the marketplace became increasingly competitive. Many of the geotechnical giants, such as Law, Chen, Woodward-Clyde and Dames and Moore, either purchased other firms or were themselves purchased in a series of corporate take-overs and re-structuring, intended to make firms more profitable in the 1990s. Many midsize firms disappeared from the scene because they were incapable of competing with large firms in six and seven figure contracts and were usually underbid by smaller firms for low end work.

Many of the more experienced engineers caught in corporate takeovers soon grew weary of the new expectations thrust upon them. Everyone was subject to "job training", which often included phrases such as "you have to learn to become a client advocate", as a politically correct phrase to describe lying to regulators about geoenvironmental data lest their clients might fire the firm and retain the services of someone else. Most of these individuals had come up through the ranks during the tenure of the Brooks Act, when qualifications-based selection promoted engineering excellence and little or no thought had been paid to "business advocacy". Everyone was expected to do whatever ever their competitors were doing in order to remain in business. It's a concept that used to be termed "comparative morality", and the fallout of such egregious practices are just starting to be felt in corporate America in mid-2002, as this is being written.

Many of these dissatisfied engineers and geoscientists opted to leave the corporations and start small consulting firms, with nothing but a desk, a phone, fax and PC with Internet connection. Small emerging firms proliferated onto the urban scene in the 1990s. In 2000, approximately 65% of the geotechnical firms advertising their services in California did not exist 8 years earlier! This surprising rate of start-ups has not been seen since the decade following World War 2 (1945-55). Many engineering geologists found themselves refugees from the collapse of the low-end (yank-a-tank) geoenvironmental market that collapsed in the mid-1990s. They were faced with changing professions or re-inventing themselves. Many became sole proprietors, working as hourly consultants for small engineering firms.

INCLINATION TO ACCEPT INCREASING RISK

There has been an increasing trend, nationwide, for owners, government agencies and consumers to accept increased risk during periods of economic growth, which typified the decade of the 1990s. Builders have been taught to spread risk by requiring their engineering consultants and the engineer's sub consultants to show proof of errors and omissions insurance and to acquiesce to performance warranties and guarantees in their contracts (Prime, 1993). If lawsuits arise during construction or afterwards, everyone connected with the project can expect to be sued (Olshansky and Rogers, 1987).

A fundamental problem with assuming increased risk in geotechnics is the relative inability to accurately estimate such risks with any reasonable degree of certainty. It is then difficult, if not impossible, to apprise clients of just how much risk they are incurring by choosing a certain course of action. The geoscientist cannot predict future events if they don't know how often a particular event has occurred in the past. The fundamental challenge in developing probabilistic hazard assessments for earthquakes over the past 30 years was the paucity of recurrence interval data. If the data does not exist, accurate risk assessments are impossible.

So, informing one's clients of "increased risk" has become a cliché they expect to hear, but cannot really appreciate the implications thereof. Owners who are more experienced and have been burned in the past tend to become more conservative and less inclined to risk taking. This same adage applies to consultants. It has been the author's experience that the less experienced geologists tend to accept marginal projects because they are often hungry for work and don't really comprehend the risks they are incurring, because they haven't been burned yet. Less experienced geologists can also fail to recognize clients with unrealistic expectations, which should be avoided if possible.

POTENTIAL IMPACTS ON PROJECT LONGEVITY

Increased competition will likely have a long-range detrimental impact on project longevity. This aspect can be understood by analyzing the unprecedented infrastructure constructed during the Second World War. The unit costs for military structures, housing, roads, airfields and pipelines were all-time lows; because engineering input was minimal, for the most part standardized and non site-specific. In addition, wartime labor was willing to work longer hours for less pay, out of a sense of patriotism and common cause. On paper, businessmen would look at the unit costs of those projects and regard them as being exemplary of what can be accomplished with tight-fisted management practices.

What doesn't show up in a conventional economic analysis is the long-term payback of these thrown-together wartime facilities. Most of these facilities were intended to be temporary, for the duration of the war. About 77% of those structures were abandoned or dismantled after the war ended. If we walk the path of "low bidder takes all", history shows we will pay some increased costs down the road because under-engineered projects seldom last as long as well-engineered ones. Bluntly stated, they tend to "weather" prematurely and fall apart.

Diminished project life will ultimately trigger a series of hidden costs to society, to be paid by succeeding generations of owners and occupants. Unlike past eras, today's culture is increasingly over-leveraged in debt. The greatest share of this increasing debt has been placed in real estate; usually people's primary residences. Throughout the 1990s the nation witnessed increasing levels of re-financing personal real estate to reduce monthly payments or pulling cash out to apply to other business opportunities or family needs. Each time a residence is re-financed the term of the loan begins anew, and homes in more affluent suburban areas may be refinanced two to three times, stretching the loan payments out to 40 and 50 years before the home can be paid off. That many of our populace are over-leveraged is evident by the record number of loan foreclosures that occurred during the last decade.

In most states the statute-of-limitations for patent defects of manufactured products, like cars or homes, is between 1 and 4 years. The limitation for latent defects is usually between 5 and 10 years. For years engineers and builders have designed and built structures with these limitations in mind, with the assumption that occupants will knowingly absorb the burden of maintenance and upkeep. New structures tend to require less maintenance and upkeep than older structures, and if maintenance is deferred, these costs can swell to significant values 20 to 50 years after a structure is built. If current trends continue, we can expect only 20% to 50% of homeowners in the affluent suburbs will live to see their homes paid off while they (both principal income earners) occupy them!

Over-leveraging home loans has caused increased incidence of lawsuits in California and other population centers. Foreclosures and lawsuits appear to be influenced by nation-wide slumps in the economy, when earnings are often diminished. Builders, their consultants and contractors can all be named in class action suits using legal theories that are not bound by normal limitations statutes. Fraudulent concealment of some geotechnical hazard, such as ground settlement, swelling or slope creep are several of the legal theories often used to allow filing of lawsuits years past limitations statutes. These cases often involve dozens of players whose services were performed many years previous. In one California case, a slope failure occurred in 1974, 21 years after it was placed. The fill was alleged to contain trees and other organic matter which had not been disclosed. The plaintiffs were able to recover damages from the original contractor in 1982, 29 years after the incident occurred (California Appellate Court, 1982). In those states, like California, which recognize joint-and-several-liability law, geoscientists, if found only 5 percent negligent, may incur a larger share of liability if other defendants are judgment proof (California Supreme Court, 1978). It would appear that legal expenses will continue to grow in the years ahead and become a major factor in determining firm's longevity.

If buildings or surrounding improvements are experiencing "problems", owners may be tempted to pursue litigation through performance standard theories, alleging improper disclosure of the likelihood of future problems or a host of other tort theories.

The introduction of so-called "performance standards" in the new International Building Code may create an increasingly volatile situation for geoscience professionals in coming years, depending on how their contractual obligations to engineers, developers and contractors are crafted.

CONCLUSIONS

Over the past quarter century it would appear that the valuation of engineering geologic input on geotechnical engineering projects has gradually diminished. During that same interim, engineering geology was rescinded as a required course from most academic curriculums and the market place for engineering geologists has become increasingly competitive. More and more geoscientists have found themselves working as sole proprietors and contract employees for engineers, despite the achievement of licensure in 30 states and Puerto Rico by 2002. Owners and many engineers appear more willing to accept deferred risks, assuming insurance and other loss prevention practices will deter judgments from being pressed upon them. It is not clear what can be done to reverse this trend, short of the engineering profession experiencing some high-visibility ground failures, as have occurred in the past.

Petroski (1995) describes a research project in Great Britain that studied cycles of bridge failures, which concluded that they tended to occur on 30-year cycles, over a 130-year period of study. This recurrence was thought to be caused by communications and generation gaps between engineers of different times, who tend to discount the methods and forget the lessons learned by their predecessors. A similar cycle appears to have occurred since 1970 in regards to engineers appreciating the role geology plays in influencing the outcome of their projects.

Lapses in site characterization have, more times than not, been successfully defended as "acts of God" (Morely, 1996), which are alleged to have occurred because of "unforeseeable" site conditions. In reality, very little is foreseeable when project managers or owners make a conscious decision to circumvent thorough subsurface explorations to save money. Market forces will likely continue to drive down site characterization costs, because these are not profitable. Just how low things will devolve remains to be seen. A number of mainstream developers have actually changed their focus to enact greater conservatism in their products to better insulate themselves from future lawsuits. Most engineers have dodged paying large judgments by filing bankruptcy and re-forming as another entity. Those sole practitioners and contract employees that are not insured are not major targets of litigation.

In the coming years engineering geologists will need to reinvent themselves by showing engineers the new tools and techniques at their disposal that can provide safer projects with less long-term liability. Like their engineering brothers, they must change with the times, but continue to resist the temptation to sacrifice quality for cost and incur undue risk.

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