

## WHITE PAPER ON GEOENVIRONMENTAL ENGINEERING

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### Geoenvironmental Research Experience (past 5 years):

1. Contaminant transport in consolidating soils
2. Numerical modeling of waste sludge consolidation
3. Shear strength of geosynthetic clay liners
4. Evaluation of large database of GCL internal and interface shear strengths
5. Shear strength of GM/GCL interfaces
6. Effect of progressive failure on measured geosynthetic interface shear strength
7. Field study of installation damage for GCLs
8. Evaluation of CBR bearing capacity test for GCLs
9. Measurement of hydraulic conductivity of GCLs covered with coarse soils
10. Effect of hydraulic gradient on measured hydraulic conductivity
11. Evaluation of fly ash for construction of highway embankments
12. Evaluation of loess-fly ash mixtures for roadbase construction
13. Evaluation of foundry sand for construction of highway embankments
14. Modeling of pore-scale flow and transport through porous media
15. Analysis of stability of slurry wall trenches

### Geoenvironmental Teaching Experience (past 5 years):

#### Formal Courses

*Groundwater and Seepage* – Spring 2003

*Geoenvironmental Engineering* – Spring 1998, Spring 2000, Spring 2001, Spring 2002

#### Short Course Presentations

##### *Stability of Landfill Liner and Cover Systems*

1. Part of UW-Madison short course *Slope Stability and Landslides*, UCLA, January 2000
2. Part of UW-Madison short course *Slope Stability and Landslides*, UCLA, February 2001
3. Part of UW-Madison short course *Slope Stability and Landslides*, UCLA, February 2002
4. Santa Ana Regional Water Quality Control Board, Riverside, CA, August 2002
5. Part of UW-Madison short course *Slope Stability and Landslides*, UCLA, February 2003
6. Ohio EPA, Columbus, OH, July 2003

### **Geoenvironmental Consulting Experience:**

Los Angeles County Sanitation District – Prepared state-of-the-art report on internal and interface shear strengths of geosynthetic clay liners for landfill bottom liner systems, 2001.

Los Angeles Unified School District – Member of five-person Scientific Advisory Team appointed to assist the Independent Belmont School Commission with regard to proposed remediation measures for methane and hydrogen sulfide gas discovered on the construction site of the Belmont Campus, 1999.

Parsons-Brinckerhoff – Member of two-day task force to develop ideas for the beneficial reuse of 6 million yd<sup>3</sup> of New York Harbor dredgings, 1999.

URS Greiner Woodward-Clyde – Prepared state-of-the-art report on geosynthetic clay liner internal and interface shear strengths for landfill bottom liner systems, 1998.

Colloid Environmental Technologies Co. – Ex Expert witness (deposition) on possible causes for the hydraulic failure of a geosynthetic clay liner system for a wastewater treatment pond in Dillon, MT, 1998.

Northern Indiana Public Service Company, Inc. – Performed laboratory testing program for evaluation of engineering properties of compacted coal ash, 1994 - 1995.

Golder Associates, Inc. – Evaluated design of landfill cover system for Hanford, WA, hazardous waste site, 1993.

## **Appraisal of Geoenvironmental Research, Education, and Practice:**

To provide my appraisal of geoenvironmental research, education and practice, I would like to first begin with a discussion of “geoenvironmental engineering”. I would define geoenvironmental engineering as all engineering efforts to place, contain, control, or clean up contaminants below the ground surface. Examples include solid and hazardous waste disposal in landfills, entombment of radioactive wastes, and remediation of brownfields and Superfund sites. The range, properties, and variability of both the contaminants and the geologic materials that contain them are vast. Add to this possible biodegradation, NAPLs, chemical and radiological reactions, three-phase media, and facilitated transport, and it becomes immediately clear that the variety and complexity of the problems encountered in the field of geoenvironmental engineering is truly staggering. So staggering, in fact, that it is doubtful that precisely accurate deterministic modeling efforts will be possible in many cases. For this reason, continuing development and use of probabilistic methods is needed in geoenvironmental engineering.

The subject matter of geoenvironmental engineering crosses many traditional academic disciplines, including environmental engineering, geotechnical engineering, chemical engineering, materials engineering, hydrogeology, microbiology, environmental science, soil science, and applied mathematics. As the scope and complexity of the problems encountered is often beyond the bounds of any one discipline, geoenvironmental engineering is truly an interdisciplinary field in which a team of specialists are often required to arrive at an optimal problem solution.

Considering the broad scope of geoenvironmental engineering, only the rare individual will have the necessary background and expertise to participate in all aspects of the problems encountered in practice. This begs the question: “What components of geoenvironmental engineering are best suited to each professional specialty?” Environmental and chemical engineers are best qualified to assess and design chemical and biological processes associated with waste disposal and remedial activities. Example applications include design of bioremediation and chemical surfactant cleanup of subsurface contaminants and evaluation of life-cycle degradation processes in solid waste landfills. Geotechnical engineers distinguish themselves with the ability to characterize hydraulic, deformation, strength, and volume change behavior of geomaterials and geosynthetics. Many of these activities fall under the specialized field of “waste geotechnics”. Example applications include site characterization, material testing, design of waste disposal facilities, evaluation of settlement from pumping operations, and dredging, dewatering, and disposal of contaminated sediments. Hydrogeologists are specialists in groundwater flow and subsurface contaminant transport. Example applications include flow and transport modeling, design of pump-and-treat systems, well installation, and field monitoring of groundwater quality. Other disciplines generally provide supporting technical assistance to these primary specialties.

To understand the future of geoenvironmental engineering research, education, and practice, we must first understand the motivation for innovation in this field. Geoenvironmental engineering projects are not a source of revenue for owners and responsible parties but are a source of cost. Innovation is not driven by prospects of future revenue, but by the prospect of reduced cost (which is a less powerful motivator). In addition, there are often financial and legal disincentives to accelerate cleanup efforts and to experiment with new technologies. As a result, motivation for innovation in geoenvironmental engineering has generally not come from the private sector. Instead, innovation has been motivated by legislation and directives of regulatory

officials. In response, geoenvironmental engineering practice has had to make tremendous progress in the past 30 years – beginning in the mid-1970s with practically no knowledge of current methods. Since then, legislation has been enacted, analysis and design methods have been developed, standards of practice and materials testing have been established, new technologies and materials (e.g., geosynthetics) have become available, and analysis and design software programs have been written. Advancements have come swiftly, with the pace of practice perhaps peaking in the early 1990s. Since then, practice has been steady but no longer in a period of rapid growth. Growth has diminished because funding has reduced, legislation is largely in place, and most of the immediately threatening contaminated sites have been addressed. Without the impetus of changing legislation, developed methods are largely satisfactory although incremental improvements continue for reasons of economy or improved effectiveness.

The needs of practice and high levels of funding from government sources have driven extensive research in geoenvironmental engineering. The peak activity level for geoenvironmental research lagged the peak activity level for practice by several years, but now funding levels have reduced and the period of high growth in geoenvironmental research has likely passed. For example, the U.S. Environmental Protection Agency has all but disbanded their research on solid waste disposal in recent years. In response, the pace of new published research has declined. For example, submission rates of geoenvironmental manuscripts to the *ASCE Journal of Geotechnical and Geoenvironmental Engineering* are at a significantly reduced level compared with five years ago. Research levels are now steady with the most dedicated and capable individuals pursuing the remaining problems.

Finally, geoenvironmental engineering education has lagged the pace of research and improvements continue to occur. In my estimation, geoenvironmental education has never been better than it is today. Most university programs have courses in place to treat the necessary topics. These courses are generally offered by civil engineering departments although coverage can also be found in earth science and environmental science programs. Textbooks are now available on many topics in geoenvironmental engineering. Short courses are regularly offered by universities and professional organizations (e.g., ASCE). Education in geoenvironmental engineering is limited by the same vastness of topic as discussed earlier and students generally concentrate in one of the more traditional specialties (e.g., geotechnical engineering, environmental engineering). Truly integrated, multidisciplinary programs in geoenvironmental engineering education are atypical if not rare.

## **Perspective on Emerging Geoenvironmental Issues and Technologies:**

Based on the previous discussion, some extrapolation may be possible toward the future of geoenvironmental engineering. In my estimation, geoenvironmental engineering is becoming increasingly mature as the critical problems are addressed, legislation remains largely unchanged, and owners, responsible parties, and regulators become more educated on the capabilities of various available technologies. Research funding levels are likely to remain steady in the near term. In the long term, research funding is unlikely to increase dramatically and may even decline from current levels. Research activity levels should remain steady and improvements to geoenvironmental engineering education will continue.

During the past 30 years, progress in geoenvironmental engineering was often unbridled, even chaotic at times. Those days are thankfully over. Geoenvironmental stewardship has never been better and we, as geoenvironmental professionals, have done an excellent job in helping to protect human health and the environment. As our experience base continues to grow, more technologies will become prescriptive for certain types of geoenvironmental problems.

As in the past, future research efforts in geoenvironmental engineering will be largely governed by funding availability. I suspect this funding will be targeted to specific, high-priority problems and directives. From my largely geotechnical engineering perspective, the following problems might fall into this category:

- Improved methodologies for geoenvironmental site characterization (e.g., push technology and non-invasive)
- Development of real-time sensor arrays for geoenvironmental monitoring
- Development of modified clays (esp. modified bentonite) for hydraulic barriers
- Seismic stability of geoenvironmental systems
- Remediation of contaminated sediments
- Remediation of DNAPL sites
- Stability, settlement, and potential long-term contamination of bio-reactor landfills
- Continued development of beneficial uses for waste materials
- Long-term reliability of waste disposal facilities (esp. hazardous and radioactive wastes)
- Development of probabilistic methods for geoenvironmental analysis and design