MICHAEL BAILEY, P.E.

POLLUTION CONTROL HEARINGS BOARD
FOR THE STATE OF WASHINGTON

AIRPORT COMMUNITIES COALITION and CITIZENS AGAINST SEA-TAC EXPANSION, Appellants, v. STATE OF WASHINGTON DEPARTMENT OF ECOLOGY, and THE PORT OF SEATTLE, Respondents.	PCHB No. 01-160 **PREFILED TESTIMONY OF MICHAEL BAILEY, P.E.**

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Outline of Testimony

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1. I have personal knowledge of the facts stated in this testimony and would be competent to testify to those facts.

INTRODUCTION

2. I am the Project Manager for geotechnical engineering for the Port of Seattle's Third Runway Project. I am a registered Professional Engineer in Washington and a Senior Principal with the Seattle-based firm Hart Crowser, Inc., which is a sub-consultant to the lead design firm, HNTB Corporation. A copy of my curriculum vitae is attached as Exhibit A.

SUMMARY OF OPINIONS

3. The purpose of this testimony is to describe the extensive design process for the Third Runway embankment and MSE walls, a process in which the Port of Seattle has relied on reputable engineering firms, a technical review board consisting of internationally recognized experts, a national building code, and independent methods of confirmatory analysis that go beyond requirements of the code. The Port's design team established a reasonable basis of design for the Third Runway embankment and MSE walls. Extensive peer reviews have verified that the work meets the standard of practice for structures of this type.

4. The Port's design includes, but does not solely rely on, use of the advanced finite difference computer model FLAC, to provide redundant verification of performance based on analysis of seismic stresses and resulting deformations. While the design was completed without relying solely on the FLAC model, the FLAC analysis is a credible tool for independent evaluation of the design, based on comparison of analyses, both static and seismic, with results of model tests in published research reports by others. The design team has concluded that the FLAC analyses performed are valid.

5. The Port has based design on a seismic design event with a 10 percent probability of exceedence in 50 years (average return period of 475 years), which is consistent with practices: a) used on other commercial and transportation facilities; b) set forth in the building code requirements for most cities in the immediate area; and c) set forth in the National Code published by the American Association of Highway Transportation Officials

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(AASHTO, 1996-2000). The Port has exceeded the standard of practice for ordinary transportation infrastructure by utilizing redundant methods of analysis and a combined probabilistic and deterministic seismic hazard assessment that was specifically developed for the site.

OVERVIEW OF EMBANKMENT

6. The proposed Third Runway will be constructed partially on an embankment of compacted earth fill, so that the new runway elevation matches the existing airfield. In order to accommodate the slope of the existing terrain, the new embankment will vary up to a maximum fill thickness of about 165 feet. The new embankment is being constructed as a zoned earth fill, with specific types of soil materials and compaction requirements used in different areas to provide necessary stability, drainage, and settlement characteristics. Overall, the new embankment will include about 17,000,000 cubic yards of compacted earth fill. New embankment side slopes will have an average inclination of 2H:1V. Three mechanically stabilized earth (MSE) retaining walls will be used to limit the extent of embankment slope in the vicinity of wetlands that are tributary to Miller Creek. These walls will have exposed faces that range up to maximum heights of 50 to 135 feet above ground.

7. Significant geotechnical aspects of the project include the analysis of foundation stability, including seismic stability for the embankment and the MSE retaining walls, and the effects of construction on the adjacent wetlands.

OVERVIEW OF DESIGN FOR THE EMBANKMENT AND MSE WALLS

8. Design of the Third Runway embankment and MSE walls has been carefully implemented in a logical manner, over a period of several years. Contrary to the implications of ACC's consultants, the Port's design team has studied all significant aspects of the project, and the project's impacts, and has provided a design that is workable, scientifically sound, and protects area wetlands and streams. The design team is led by HNTB Corporation, which provides civil engineering and construction oversight. HNTB's sub-consultants include Hart Crowser, Inc., which is responsible for geotechnical engineering, and the Reinforced Earth

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Company (RECo), which is designing the MSE walls. Figure 1, in Exhibit B provides an organization chart for the design team and independent technical reviewers. Qualifications of these firms and other key individuals are discussed below.

9. Recognizing that retaining walls would be needed to limit the extent of filling along Miller Creek, the Port of Seattle evaluated eight types of retaining wall, and more than 60 wall and embankment slope geometric arrangements before selecting the proposed MSE walls for the project. The methods and results of that evaluation are presented in the report entitled: *Draft Evaluation of Retaining Wall/Slope Alternatives to Reduce Impacts to Miller Creek Embankment Station 174+00 to 186+00, Third Dependent Runway*, that was prepared for the Port by HNTB Corporation, Hart Crowser, Inc., and Parametrix in April 1999. (A listing of all the documents cited is presented in Exhibit C).

10. Subsurface borings and tests were completed to define the soil and groundwater conditions that affect construction and future performance of the embankment and MSE walls for the Third Runway. This information is presented in a number of reports: AGI 1996 and 1998; CivilTech 1997 and 1998, HWA Geosciences 1998; Hart Crowser 1999a, 2000a, 2000b, 2000d, 2000f, 2000g, 2001b, and 2001c.

11. The design team recognized several years ago that native soils under some parts of the embankment were soft or loose and would not provide a suitable foundation (Hart Crowser, 1999b). Preliminary geotechnical stability and settlement analyses were used to delineate the extent where "subgrade improvements" are needed to mitigate silt, clay, and peat soils that are too weak or compressible to provide good support, as well as areas where weak sandy soils are subject to loss of strength due to seismic shaking (termed "liquefaction"). The Port evaluated nine alternative methods for accomplishing these subgrade improvements below the MSE walls (Hart Crowser, 2000e). The need for some areas of subgrade improvement below the new embankment, and mitigation for the potential environmental impacts of construction were reported in the Port's Wetland Functional Assessment and

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Impact Analysis (Parametrix, 1999, 2000a, and 2001b) and the Comprehensive Stormwater Management Plan (Parametrix, 2000b).

12. Two of the methods selected for making subgrade improvements were (1) use of stone columns for support, and (2) excavation and replacement of problematic soils. Although ACC's consultants at Geosyntec claim that selection of the excavate and replace option is a recent design change, that approach has been an ongoing part of the design for quite some time.

13. After establishing the initial layout for subgrade improvements, the Port completed several additional analyses of stability and deformation. A major part of the design effort has involved analysis of potential seismic effects, including identification of a reasonable seismic basis of design and analysis of shaking and liquefaction effects. Design of the MSE walls conforms to current provisions of a national code for transportation structures, published by the American Association of Highway and Transportation Officials (AASHTO, 1996-2000), that is discussed later in this testimony in more detail. In addition, the design team used several independent methods of analysis and obtained consistent results, which indicates that the proposed design is sound. Throughout this process, HNTB utilized an independent review panel, composed of internationally recognized engineering experts, to review the design work in progress and verify that the engineering methods are appropriate.

14. Concurrent with stability analyses for final design of the MSE walls, the Port accomplished hydrologic analyses to assess potential environmental impacts, and made plans for construction mitigation (Parametrix, 2000b and 2001a; current mitigation plans are described in HNTB, 2002). The stability analyses are discussed in greater detail below.

15. At the present time, geotechnical analyses of stability and deformation for the three proposed MSE walls are complete. Hart Crowser has made recommendations for slight modification of the reinforcing zone geometry and the required areas for subgrade improvement have been verified. While final construction plans, schedule and phasing are

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contingent on resolution of permit issues, no changes to design are anticipated that would lead to any new environmental impacts of construction.

QUALIFICATIONS OF THE DESIGN TEAM & INDEPENDENT TECHNICAL REVIEWERS

16. The Port's design team for the Third Runway embankment and MSE walls includes three internationally recognized engineering firms, whose work is monitored by a distinguished independent review board (see Figure 1 in Exhibit B).

17. HNTB Corporation is the engineering project manager and civil engineer for the Third Runway project. In business since 1914, HNTB provides engineering and architectural design, planning and construction management for major transportation infrastructure projects. Recent airport experience includes major airport expansion and renovation projects at George Bush Intercontinental Airport in Houston, Midway Airport in Chicago, and Dulles international Airport near Washington D.C. HNTB's work is directed by Jim Thomson, P.E., an experienced Civil Engineer who has had direct responsibility for Third Runway construction for the past three years.

18. HNTB selected the Reinforced Earth Company (RECo) to design the MSE walls for the Third Runway project and Hart Crowser Inc. to provide geotechnical engineering services.

19. RECo was chosen as MSE wall designer for the Port of Seattle since they have more extensive experience with design and construction of high MSE walls than anyone else in the world.

- RECo has designed and constructed thousands of MSE walls, including 12 that are more than 90 feet high. RECo designed two MSE walls that were built to about the same height as the maximum proposed wall height at Sea-Tac: a 137–foot-high wall built in 1979 in South Africa and a 133-foot-high wall built in Hong Kong in 1993. These walls were successfully constructed and have preformed well for some time.

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- Hart Crowser Inc. is a local geotechnical engineering firm with more than 25 years experience in the Seattle area. Hart Crowser has been lead geotechnical engineer on major infrastructure projects such as the US Navy Home Port in Everett and high-rise buildings in downtown Seattle, such as the Millennium Tower. Hart Crowser has been responsible for stability analyses for the right abutment at Mud Mountain Dam for the Corps of Engineers, Cedar Embankment at Chester Morse Lake for the Seattle Water Department, as well as major tailings embankments for the mining industry. Hart Crowser has been responsible for design of MSE reinforced slopes that have been successfully constructed up to 150 feet in height.

20. Hart Crowser utilized experienced professional engineers in all phases of data collection and analyses. These include Michael Bailey, P.E., Geotechnical Project Manager; Dr. Barry Chen, Ph.D., P.E., Senior Associate Geotechnical Engineer; and Michael Kenrick, P.E., Senior Associate Hydrogeologist. Doug Lindquist, P.E., and Reda Mikhail, P.E., were responsible for many of the engineering analyses. Hart Crowser has also retained expert sub-consultants from the University of Washington to provide special geotechnical assistance on the Third Runway design team. These experts include:

- Professor Robert Holtz, Ph.D., P.E., an internationally recognized MSE expert;
- Professor Steve Kramer, Ph.D., P.E., an expert in earthquake engineering; and
- Professor Pedro Arduino, Ph.D., an expert in geotechnical computer modeling.

21. In addition, Hart Crowser relied on a number of other specialty contractors with significant local experience: Dr. John Hughes (*in situ* testing using the soil pressure meter); GeoRecon International (geophysical measurements of shear wave velocity); Northwest Cone (cone penetrometer testing); and Holt Drilling (drilling for soil sampling and installation of monitoring wells).

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22. Beginning with the process of identifying and evaluating alternatives and continuing through design, the Port of Seattle also relied on independent technical reviewers to provide input to design.

- During its initial assessment of different types of retaining walls and wall/slope combinations to identify the best means of limiting the embankment impact to adjacent wetlands, HNTB used peer review by the geotechnical firm Shannon & Wilson to verify the selection of MSE technology as the best alternative to limit embankment impacts to wetlands. This peer review evaluation included consideration of seismic performance, constructability, historical performance, and cost effectiveness (Shannon & Wilson, 1999).
- After selection of MSE walls to limit wetland impacts, the design team consulted with in-house staff and with Professor Robert Holtz, Ph.D., P.E., at the University of Washington and Mr. Tony Allen, P.E., at the Washington State Department of Transportation, to determine appropriate criteria for selection of an MSE wall design engineer for the Third Runway. Professor Holtz continues to provide review and consultation to the Port's design team. Mr. Allen is the State Geotechnical Engineer for the Washington State Department of Transportation. He has participated extensively in developing national standards for MSE design through his work with the AASHTO.

23. In order to provide additional technical input and further verification of the design work in progress, HNTB retained the services of an internationally recognized group of eminent engineers to form a special technical review board. The board members include:

- **Dr. James K. Mitchell, Ph.D., P.E.,** is a University Distinguished Professor Emeritus at the Virginia Polytechnic Institute and State University and former Chairman of the Civil Engineering Department at the University of California, Berkeley. Professor Mitchell is an expert in soil behavior, ground improvement, and earth reinforcement.

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- **Dr. I.M. Idriss, Ph.D., P.E.,** is Professor of Civil Engineering at the University of California at Davis. Professor Idriss is a recognized authority on earthquake engineering and on seismic performance of embankments and MSE walls.
- **Dr. Barry Christopher, Ph.D., P.E.,** is an independent geotechnical engineering consultant and internationally recognized expert in MSE wall design, construction and performance.

24. The Embankment Technical Review Board (ETRB) is coordinated by **Mr. Peter Douglass, P.E.,** an independent geotechnical consultant who has earned advanced degrees in civil engineering and geology and has more than 30 years of geotechnical engineering experience in the Seattle area as well as around the world. Resumes for the Technical Review Board members are included in Exhibit D to this testimony.

25. In late 2000 and throughout 2001, the ETRB was given all the engineering data, design reports, results of calculations, and MSE design plans, for review and comment. Some or all of the members of the Board met with the Port's design team on six occasions in the period November 2000 to October 2001, each meeting lasting 1 to 3 full days. In addition, the design team participated in several conference calls with the ETRB, enabling further expert review and input to the ongoing site explorations, analyses, and design.

26. Working closely with the Port's design team, the ETRB developed a good understanding of geotechnical issues pertinent to design and construction of the Third Runway. Drawing on their extensive expertise with analysis of earthquakes, soil reinforcement, and soil behavior, the Board concurred with the approach taken by the design team. The Board also provided recommendations for additional analyses to improving the accuracy and/or to provide independent verification of the analyses, and these have been accomplished by the design team.

DESCRIPTION OF MSE WALLS AND WALL DESIGN

27. This section describes MSE walls and the process the Port is using to assure that the design meets appropriate standards for safety and reliability.

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Wall Description

28. The Third Runway project includes three proposed MSE walls, referred to as the North, West, and South Walls. All of the walls vary from zero height at each end, up to a maximum height in the interior portion of the wall's length. The North Wall is about 1,300 feet long and varies up to a maximum height of about 90 feet. The West Wall is about 1,450 feet long and varies up to a maximum height of about 135 feet. The South Wall is about 900 feet long and varies up to a maximum height of about 50 feet.

29. The three retaining walls proposed for the Third Runway project will be constructed of "mechanically stabilized earth," a technique that uses steel or other material to reinforce soil. The specific type of MSE walls being designed for the Third Runway will utilize strips of steel layered in the compacted soil fill, and a relatively thin reinforced concrete facing to form a near vertical retaining wall face. The reinforcing strips extend into the embankment fill behind the wall, perpendicular to the wall face (see Figure 1, in Exhibit E). Friction between the strips and the layers of compacted soil prevents the strips from pulling out, and supports the wall face.

30. MSE walls have been used around the world, with exposed face heights of up to about 140 feet. Reinforced soil walls have been in common use for more than 30 years. This type of wall provides very good seismic performance compared to other types of retaining wall. During an earthquake, the reinforcing strips are able to move within the soil in response to shaking, while allowing the overall mass of the reinforced zone to remain stable.

31. Another advantage of MSE walls is that construction does not require disturbance of a large area outside the footprint of the reinforced zone, even where subgrade improvements are accomplished as discussed later in this testimony.

32. Finally, the completed MSE walls will not impede groundwater seepage or reduce base flow to the wetlands and Miller Creek. This is because: (a) the cross sectional area of the steel reinforcing strips in aggregate is small compared to the overall cross section of

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the reinforced soil mass, and (b) the concrete wall facing includes regularly spaced joints that permit seepage (Hart Crowser, 2000h).

Wall Design Process

33. MSE walls for the Third Runway are being designed to satisfy all of the following three criteria:

1) Design requirements in the AASHTO code for MSE walls (AASHTO 1996-2000);

2) RECo in-house criteria, which include results of both theoretical and empirical methods of analysis, and performance criteria based on construction of similar walls; and

3) Verification by independent analyses (a) that RECo's design meets the target factor of safety criteria for both global and compound stability; and (b) that the proposed design will result in acceptable deformations for the design level of seismic shaking.

34. The AASHTO code is a nationally developed standard that is used for design of transportation infrastructure. The current code is the 16th edition, which was published in 1996 and has been updated by addenda each year from 1997 through 2000, and 2000 is the most recent revision. Building codes are dynamic — there are always peer groups from state transportation departments and private industry working to incorporate new information and "lessons learned" to improve the code. The fact that efforts are underway to consider revising the AASHTO code, as described by Dr. Kavazanjian, does not mean that the current AASHTO code is inadequate for the Third Runway project. Mr. Tony Allen, Geotechnical Engineer for the Washington State Department of Transportation, and advisor to HNTB during the early stages of the Third Runway design, is actively involved in updating the AASHTO code on MSE walls. The Third Runway MSE walls are being designed to conform to the AASHTO code in part based on Mr. Allen's recommendations.

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35. The second part of the design criteria described above allows the Port of Seattle to benefit from the experience RECo has acquired in designing, construction and monitoring the performance of MSE walls for the past 30 years. RECo has designed and built more than 23,000 MSE structures in 37 countries (Elias, Christopher & Berg, 2001). Recognizing that RECo has more experience designing high MSE walls than anyone else does in the world, HNTB and RECo agreed that the wall design would follow RECo's in-house criteria wherever these are more stringent than requirements of the AASHTO code.

36. Finally, Hart Crowser is using several methods of analysis to verify that the foundation for the MSE walls is stable and that the walls and embankment will perform satisfactorily during an earthquake. This includes several forms of what are termed "global" and "compound" stability analyses, and deformation analyses, as discussed below. Global stability refers to potential failure modes exterior to the reinforced zone; compound stability refers to potential failures through the reinforced zone. In a few cases, these independent analyses led Hart Crowser to develop recommendations for modifying the MSE reinforcing design to include more reinforcing and/or to extend the reinforcing farther or deeper than required by the AASHTO code or RECo's own analyses.

37. The use of three criteria discussed above, as well as redundancy in the types of stability and deformation analyses, provides assurance that the walls will perform as desired after construction, including during significant earthquakes. In addition to the stability analyses, the design team is using two different types of deformation analyses that go beyond what is required by AASHTO or RECo's conventional practice, to provide added assurance of the walls' performance. The deformation analyses are useful because they illustrate the consequence of "failure" if one were predicted by the stability analyses (which has not occurred). The MSE retaining walls are able to deform under load, which results in reduction of the stress tending to cause instability. The effect of such stress and deformation may result in a need for wall maintenance to address alignment or aesthetic issues, replace spalled concrete facing panels or other damage. Increased stress and deformations may occur in a

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larger earthquake, but catastrophic failure where the wall falls down or soil goes spilling into Miller Creek is highly unlikely to occur as a result of any earthquake.

38. The following steps were utilized in the progressive design and analysis of MSE walls for the Third Runway.

- HNTB developed the initial layout of MSE walls to fit within the embankment geometry and to avoid, or minimize as much as possible, impacts to wetlands.
- The design team met to review and discuss the design parameters, loads and details (initial geotechnical recommendations for design were presented in Hart Crowser, 2000h). Over a period of several weeks, the design team worked through regular teleconferences to review proposed design criteria and reached consensus on the basis for design, including structural, mechanical, and aesthetic details.
- Using initially assumed reinforcement geometry, limit equilibrium analyses were used to verify that design could satisfy the AASHTO code (AASHTO 1996-2000) and other design requirements for conditions at the Third Runway site.
- Analysis of preliminary sections was used to assess the need for subgrade improvement to satisfy stability and allowable settlement criteria.
- Initial wall design, including length, depth, and density of MSE reinforcing was developed by RECo, based on the design criteria and RECo design computations.
- RECo submitted design plans showing type, size and location of MSE wall and reinforcing components, for review by HNTB and Hart Crowser. RECo developed hand calculations to check and document the results of computer-based analyses. These calculations along with RECo's project Quality Assurance Plan were reviewed by Hart Crowser and HNTB. Written comments were submitted to document recommendations (HNTB, 2001).

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- Hart Crowser checked global and compound stability of the RECo design sections, and accomplished deformation analyses. Results of the stability analyses led to recommended increases in the reinforcing (Hart Crowser, 2002a) and results of the deformation analyses were provided for RECo's use in checking their design (Hart Crowser, 2002b).

39. Architectural and structural details of the MSE walls continue to be addressed as part of completing the MSE design. These include arrangement of wall facing details to accommodate vertical settlement joints; wall panel surface treatment; top of tier details, etc. Despite this ongoing work, completion of the geotechnical analyses for the walls provides assurance that completion of design will not lead to any increase in the extent of construction disturbance or post-construction impacts.

40. In accomplishing its work, the Port's design team also referred to other standards of practice for comparable engineering works, such as applicable engineering manuals developed by the U.S. Army Corps of Engineers (USACOE, 1989, 1995, and 2000). Geotechnical design work for the Third Runway is similar to what the Corps of Engineers would require for design of MSE walls and earth embankments (levees).

41. Traditionally, safety of earth structures such as embankment slopes and retaining walls has been evaluated by stability analyses, using "factors of safety" to assess adequacy of the design relative to the loads expected during the lifetime of the structure. In its simplest form, a "factor of safety" is the ratio of the forces tending to maintain stability divided by the forces tending to cause instability. The AASHTO code and other standards such as Corps of Engineers design manuals EM 1110-2-2502, EM 1110-2-1913, and ER 1110-2-1806 (USACOE, 1989, 1995, and 2000) specify target factors of safety that the design must achieve for specific methods of analysis.

42. The Port's geotechnical design procedures and resultant Factor of Safety for each specific analysis meet all AASHTO criteria, and are consistent with procedures used by the Corps of Engineers and others for design of retaining walls and earth embankments.

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Review by the independent Embankment Technical Review Board provides assurance that the methods used by the Port's design team conform to reasonable standards of engineering.

SEISMIC BASIS OF DESIGN

43. The Port's design team made a considered effort to select a reasonable basis of design to evaluate seismic effects on the Third Runway embankment and MSE walls. After review of procedures used for seismic design of other major structures and facilities, the Port of Seattle design team selected a probability-based approach that utilizes measurements from previous earthquakes throughout the Pacific-Northwest region to predict the level of future seismic shaking at Sea-Tac (Hart Crowser, 2000c, and 2001a).

44. The design team completed a site-specific probabilistic seismic hazard assessment (PSHA) that utilizes current attenuation relationships and earthquake data, which have been peer-reviewed and are extensively used in Seattle and elsewhere for design of bridges and major buildings. Use of a site-specific seismic hazard goes beyond conventional building code requirements for offices, commercial buildings, and other construction in local communities such as Burien, Des Moines, Normandy Park, Tukwila, Federal Way, and SeaTac.

45. The PSHA analysis produced a relationship between the peak seismic acceleration and average return period specific to the project site. After determining that the proposed MSE walls are "structures of ordinary importance" and not "lifeline structures," the Port is basing design on a seismic event that has a 10 percent probability of exceedence in 50 years, an average return period of once in 475 years.

46. Design using the 475-year seismic event is reasonable for the Third Runway facility. This level of event is commonly used for transportation facilities such as highway bridges and public buildings. While it is true that larger magnitude earthquakes are used to evaluate performance of some bridges and other structures, that is the result of specific circumstances for those particular structures and not a common design practice.

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47. While the Third Runway embankment and retaining walls are significant structures, they are not "lifeline structures" — they are not an essential part of airport operations that would be required as part of Sea-Tac Airport's role in recovery of the region after a major disaster. Design for the level of shaking selected for the Third Runway is consistent with the approach used for other major construction at the airport (i.e., the current South Terminal Expansion Project — a building that has thousands of people in it every day).

48. The design team is well aware of the need to maintain stability of the MSE walls to protect environmental values associated with Miller Creek, as well as to protect people in areas adjacent to the walls. Seismic performance criteria were developed for the MSE walls in order to clearly state the result of the geotechnical design process in terms that are easier to understand compared to the numeric factors of safety specified by the AASHTO code. Those narrative criteria are:

- The MSE walls and embankment fill will remain stable during and after the basis of design earthquake. Small deformations are acceptable (less than a few feet) provided stress in the retaining wall materials are typically below the value allowed by the AASHTO code;
- There will be no wetland or creek impacts due to seismic shaking of the embankment or MSE walls; and
- There will be no seismic operational impacts to the new runway.

49. In addition to verifying that the design will satisfy these performance criteria for an earthquake with an average return period of once in 475 years, the Port has accomplished additional analyses to show that the walls will not collapse during even larger earthquakes. The ten percent probability in 50 years basis of design does not mean the design earthquake will be exceeded in 50 years or even 100 years; it means that on average an earthquake of this size will occur once in 475 years. Selection of the average return period is used solely to establish the level of shaking for design, and has nothing to do with the expected service life for the MSE walls.

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50. The design included development of several ground motions that were used in progressively more sophisticated analysis as design has proceeded. This aspect of design includes expert input from the University of Washington, and has been closely scrutinized by the ETRB. Final design was based on a deterministic seismic hazard that considers the effect of an earthquake on the Seattle Fault (the largest local fault) resulting in even larger peak accelerations than predicted by the PSHA. Note that this same general approach of using a coupled PSHA (with a 500-year return period) and deterministic analysis is the same approach reportedly being used for San Francisco's current ongoing seismic assessment and upgrade for the Bay Area Rapid Transit system (Dunn et al., 2001). (There is no real significant difference between the 475-year return period used by the Port and the 500-year period chosen for BART.)

51. Finally, ACC's consultant GeoSyntec has noted that an AASHTO committee is considering revision to the seismic basis of design standard for new bridges. While this is true, such deliberations are incomplete and there is no assurance that the proposed basis of design would apply to MSE walls, or even to all new bridges, in the event that AASHTO does revise its standards in the future.

RESPONSE TO ACC COMMENTS

52. GeoSyntec has made various comments on the Port's design analyses and construction plans, which are addressed below.

FLAC is a Suitable Tool for Use as a Check on Design.

53. The Port is using a finite-difference computer model called "FLAC" as one means of independently checking performance of the wall design. GeoSyntec has suggested that results of the FLAC analysis should be validated by checking against performance of real MSE structures under loadings comparable to those expected during the design earthquake. While this would be reasonable if such experience were available, the fact is no monitoring data for an MSE wall of this size are available for an earthquake as large as the Port is using for design. This does not mean, however, that the FLAC analysis lacks utility. The design team

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includes geotechnical engineers with considerable experience using FLAC, and the analysis parameters have been carefully selected based on consideration of reported results of FLAC analyses for both MSE walls and earth dams. There are examples of relevant comparisons in the published literature. While use of scale models to check computer codes may be helpful in some circumstances, it is not common or necessary in the design of structures where there is both engineering experience and well-established design codes.

54. The Port has also used another deformation analysis procedure, the "Newmark Method." This has provided additional verification of satisfactory seismic performance of the proposed MSE walls independent of the FLAC analysis. Both of these analyses support the design chosen by the Port's team.

The Port's Analysis of Liquefaction is Consistent with Generally Accepted Engineering Practices

55. "Liquefaction" refers to the temporary reduction in shear strength that occurs in some soils due to development of excess pore pressures during an earthquake. GeoSyntec has asserted that the Port has misused the "Chinese Criteria" that are used to identify when cohesive soils (silts and clays) are, or are not, susceptible to liquefaction. GeoSyntec has also suggested that revised use of these criteria has led to great increases in the extent of soils that require "subgrade improvement" in order to provide a sound foundation for the embankment and MSE walls. While the Port has already provided a detailed technical explanation of why use of the Chinese Criteria is correct (Port of Seattle, 2001), it is also important to point out there has not been any increase in the extent of subgrade improvement as a result of further analyses of this type.

56. Final selection of overexcavation and replacement as the method for subgrade improvement followed analysis of field test results for the other alternative (stone columns) that had been considered for use at the Third Runway (out of a total of nine options originally evaluated by the Port). Final selection of the overexcavation and replacement method had nothing to do with application of the Chinese Criteria or any other analysis of liquefaction.

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Hart Crowser has completely evaluated the extent of liquefiable soils, the post-earthquake residual strength of those soils and the effect on stability and deformation of the proposed MSE walls and embankment. There has been no change in the extent of ground improvements below any of the MSE walls because of this analysis.

Subgrade Improvement Construction Plans Avoid Off-site Wetland Impacts

57. GeoSyntec has suggested that excavation to remove unsatisfactory native soils and replacement with compacted fill below the MSE walls will produce significant adverse impacts due to dewatering during construction. This is incorrect. Construction plans include use of sheet pile to limit the extent of dewatering immediately adjacent to Miller Creek. Groundwater recovered from the excavation will be applied to the wetlands. Groundwater that is unsatisfactory for land application in the wetlands (e.g., due to turbidity or sediment) will be routed to stormwater detention ponds for treatment, similar to other construction area runoff, prior to discharge.

58. The potential hydrological impacts of constructing the subgrade improvements are well understood and have been evaluated in several previous reports (for example, see Appendices E and F of the Wetland Functional Assessment and Impact Analysis, Parametrix, 2001). During construction a system of well points and shallow wells will be used to dewater the subgrade improvement construction areas. Overall flows are expected to be small (e.g., 20 to 80 gallons per minute for the entire West Wall subgrade improvement) and the extent of drawdown limited to the area immediately around the excavation.

59. During construction, near-surface soils in the dewatered area will lose water through evapotranspiration and drainage. Soil moisture will be replenished by precipitation and land application of water to the wetlands, as described above. Although some interflow and base flow in the ground may be interrupted for a period of weeks, base flow changes to the creek will be compensated for by discharge to the creek of water produced by the dewatering system. These discharges will occur in locations upstream of the excavations to ensure that creek flows are maintained.

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60. After construction, the new backfill in the subgrade improvement area will have the same ability to transmit seepage as the sandy portion of the native soils that currently transmits most of the base flow in the subgrade improvement areas. The water table will recover to pre-construction conditions within a matter of a few weeks, and there will be no significant change in the volume or rate of the groundwater flow due to the backfill.

Construction Plans Have Incorporated Means to Prevent Surficial Instability

61. During my deposition, ACC's attorney produced photographs of two surficial slough areas on the northwest face of the embankment fill, which was constructed in 2000 (the Phase 3 fill). GeoSyntec has suggested that shallow instability of the embankment and consequent erosion in these particular areas indicates some local variability in the embankment soils.

62. Permanent embankment slopes for the Third Runway, however, will not be subject to as much sloughing as indicated by ACC's photos. After development of the slough areas on the north end of the Phase 3 fill, in the fall of 2000, the Port modified the method of construction to include a more permeable soil zone on the exterior face of embankment slopes to prevent future instability of this type. The effectiveness of this measure is evident by the fact that no further sloughing occurred higher in the same slope (after the change in embankment zonation) and very little has occurred in the Phase 4 fill slopes, which were all built with this surficial zone in 2001 and so far this year. While it may not be possible to rule out all surficial instability of this type, the Port has implemented measures to avoid this condition. All permanent embankment slopes will incorporate the zone of more permeable soil on the slope face. (The area shown in the photos is an interior or temporary slope, which will be buried within the embankment when construction is completed.)

The Embankment Underdrain Will Not Reduce Existing Baseflow or Provide a Conduit for Pollution Migration

63. ACC has suggested that the embankment underdrain may act to divert seepage from the ground into swales along with stormwater runoff, and reduce the amount of

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groundwater seepage that provides baseflow to Miller Creek. ACC has further suggested that the underdrain will act as a blanket drain that collects all seepage through the fill and divert this seepage "through channels and pipes" that provide a conduit to transport existing contaminated groundwater into the creek. However, most of the precipitation that infiltrates the surface of the embankment will percolate through the embankment fill and pass vertically through the underlying drainage layer to recharge shallow perched groundwater in the native soils underlying the embankment. Some of this flow will then continue to percolate downward through the glacial till and enter the underlying shallow regional aquifer in the advance glacial outwash that underlies the area. However, should the rate of infiltration exceed the rate of percolation into the native soils below the embankment, the underdrain enables the water percolating through the embankment fill to be discharged by lateral flow to avoid any build-up of pore pressures within the embankment. In the event this occurs, the embankment underdrain would enable such seepage to flow laterally, and if any has not infiltrated down into native soils by the time seepage reaches the toe of the embankment, discharge could occur as seepage at low elevation points along the toe of the embankment. This will not result in a large volume of water or a particular "concentration" of metals or organics as alleged by GeoSyntec.

Gradation of the Underdrain Protects it From Clogging

64. Finally, GeoSyntec has suggested that functioning of the underdrain could be impaired if seismic liquefaction mobilizes native soils that could fill pore spaces in the underdrain and decrease its permeability. The underdrain soil specification requires it to be constructed of relatively well-graded sand and gravel. "Well-graded" is a geologic term that refers to a mixture of fine and coarse particle sizes, such that the underdrain is naturally resistant to intrusion of other soils (termed piping) that could cause clogging. Analysis by the design team using well-established filter criteria have demonstrated that the underdrain is not susceptible to piping from the type of native soils that are likely to be mobilized by seismic liquefaction.

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CONCLUSION

65. In conclusion, this testimony has described the extensive design process for the embankment and MSE wall, a process in which the Port of Seattle has relied on reputable engineering firms, a technical review board consisting of internationally recognized experts, and a national building code. The Port's design team established a reasonable basis of design for the Third Runway embankment and MSE walls. Extensive peer reviews have verified that the work meets the standard of practice for structures of this type.

66. The Port's design includes, but does not solely rely on, use of the advanced finite difference model FLAC, to provide redundant verification of performance based on analysis of seismic stresses and resulting deformations. The design team is satisfied that the FLAC analysis is a credible tool based on comparison of analyses, both static and seismic, with results of model tests in published research reports by others.

67. The Port has based design on a seismic design event with a 10 percent probability of exceedence in 50 years (average return period of 475 years), which is consistent with: a) practices used on other commercial and transportation facilities; b) the building code requirements for most cities in the immediate area; and c) is also consistent with the AASHTO code. The Port has exceeded the standard of practice for ordinary transportation infrastructure by utilizing redundant methods of analysis that provide consistent results, and a combined probabilistic and deterministic seismic hazard assessment that was specifically developed for the site.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct.

Executed at Seattle, Washington, this 6th day of March 2002.

Michael Bailey

Michael Bailey, P.E.

AR 015799

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TOTAL P.02

PRE-FILED TESTIMONY OF MICHAEL BAILEY, P.E.

EXHIBITS

A	Resume
B	Organization Chart for Third Runway Embankment Design Team and Independent Review Board
C	References
D	Resumes for the members of The Embankment Technical Review Board
E	Example Cross Section for West MSE Wall

A

MICHAEL J. BAILEY, P.E.

Sr. Principal Engineer, Hart Crowser, Inc.

EDUCATION

Purdue University, M.S. Civil Engineering, 1976

Michigan Technological University, B.S. Civil Engineering, with Honors, 1974

PROFESSIONAL REGISTRATION

Registered Professional Engineer: Washington & Alaska

PROFESSIONAL EXPERIENCE

Mr. Bailey has 25 years of geotechnical engineering experience, including the past 20 years with Hart Crowser, Inc. His work typically involves managing, and senior engineer responsibility for, subsurface explorations, design analyses, development of plans and specifications, and construction oversight.

REPRESENTATIVE PROJECT EXPERIENCE

- **Earth Works.** Sea-Tac Third Runway (SeaTac); Mud Mountain Dam Right Abutment Stability Improvements (Enumclaw); Golf Club at Newcastle (Newcastle); Cannon Mine Closure (Wenatchee);
- **Site Development.** Millennium Tower (Seattle); Meadowview Park (Newcastle); METRO North Operating Base (King County); Summit School (Maple Valley).
- **Underground Utilities.** Boeing Vent Tunnel (Everett); Mud Mountain Dam Outlet Tunnel Replacement (Enumclaw); Swamp Creek Interceptor Sewer (Snohomish Co.); Diagonal Avenue CSO Control Project (Seattle); Skyline Conveyance Project (Anacortes); Lake Tapps Sewerage System (Bonney Lake).
- **Transportation Infrastructure.** Valley Avenue Bridge (Puyallup); West Valley Highway (Kent); SR-5 Bridges Widening (Seattle); Friday Harbor Airport Expansion; 64th Street Bridge (Pierce Co.); SR-5 NOB Dedicated Interchange.
- **Mine Closure & Reclamation.** Holden Mine RI/FS Oversight (WA); Eureka Slope & Cumberland Prospect (Calif.); Skookum Slope Mine (WA); Wilkeson / Fairfax Mines (WA); Rio Blanco Mine (Colorado); Manhattan Canyon Mine (Calif.); two Underground Coal Mines (Confidential Client, IL).

PROFESSIONAL AFFILIATIONS

Member, American Society of Civil Engineers

Member, Society of Mining Engineers

B

Organization Chart for Third Runway Embankment Design Team and Independent Review Board

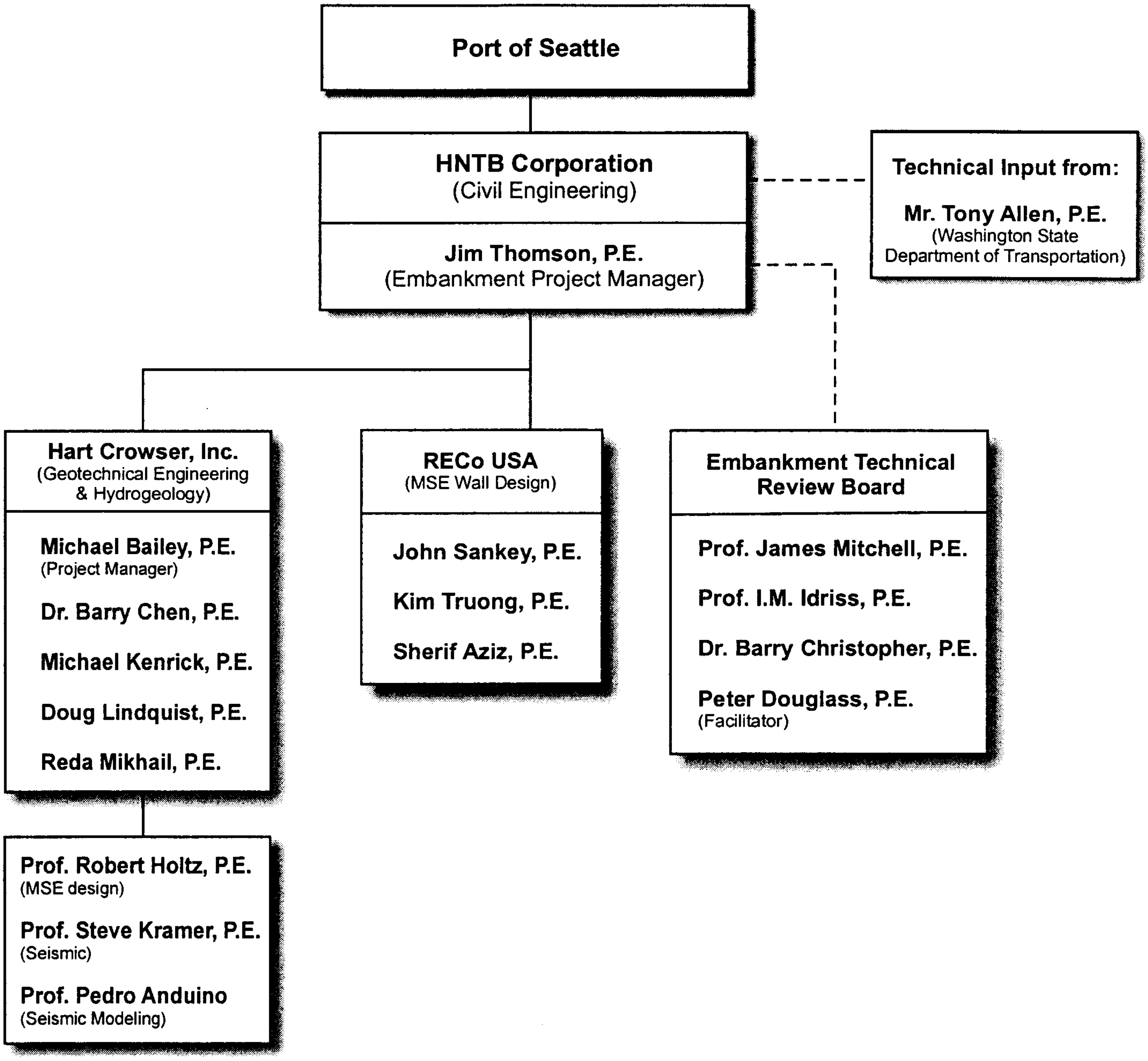

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Figure 1, Exhibit B

C

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Hart Crowser, 1999a. Subsurface Conditions Data Report, 404 Permit Support, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, July 1999.

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Hart Crowser, 2000b. DRAFT Subsurface Conditions Data Report, South MSE Wall and Adjacent Embankment, Third Runway Project, Sea-Tac International Airport, SeaTac, Washington, April 7, 2000.

Hart Crowser, 2000c. DRAFT Memorandum: Seismic Basis of Design, Third Runway. April 10, 2000.

Hart Crowser, 2000d. DRAFT Subsurface Conditions Data Report, West MSE Wall, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, June 2000.

Hart Crowser, 2000e. Preliminary Stability and Settlement Analyses, Subgrade Improvements, MSE Wall Support, Third Runway Project, June 2000.

Hart Crowser, 2000f. DRAFT Subsurface Conditions Data Report, Additional Field Explorations and Advanced Testing, Third Runway Embankment, Sea-Tac International Airport. September 5, 2000.

Hart Crowser, 2000g. DRAFT Subsurface Conditions Data Report, Phase 4 Fill, Third Runway Embankment, Sea-Tac International Airport. November 29, 2000.

Hart Crowser, 2000h. Memorandum: Proposed MSE Wall Subgrade Improvements, Seattle-Tacoma International Airport. December 8, 2000.

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USACOE, 2000. Engineering and Design, Design and Construction of Levees. EM 1110-2-1913. April 30, 2000.

D

JAMES KENNETH MITCHELL
University Distinguished Professor, Emeritus
Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Consulting Geotechnical Engineer

Dr. James K. Mitchell received his Bachelor of Civil Engineering Degree from Rensselaer Polytechnic Institute in 1951, Master of Science Degree from the Massachusetts Institute of Technology in 1953, and the Doctor of Science Degree, also from M.I.T., in 1956.

He joined the faculty of the University of California, Berkeley in 1958 and held the Edward G. Cahill and John R. Cahill Chair in the Department of Civil Engineering at the time of his retirement from Berkeley in 1993. Concurrently he was Research Engineer in the Institute of Transportation Studies and in the Earthquake Engineering Research Center. He developed and taught graduate courses in soil behavior, soil and site improvement, and foundation engineering as part of the Geotechnical Engineering Program within the Civil Engineering Department. He served as Chairman of the Department of Civil Engineering from 1979 through 1984. He was appointed the first Charles E.Via, Jr. Professor in the Via Department of Civil Engineering at Virginia Tech in 1994, University Distinguished Professor in 1996, and University Distinguished Professor, Emeritus, in 1999.

His primary research activities have focused on experimental and analytical studies of soil behavior related to geotechnical problems, soil improvement and ground reinforcement, physico-chemical phenomena in soils, the stress-strain time behavior of soils, in-situ measurement of soil properties, and mitigation of ground failure risk during earthquakes. He supervised the dissertation research of 72 Ph.D. students. He has authored more than 350 publications, including two editions of the graduate level text and reference, "Fundamentals of Soil Behavior," and several state-of-the-art papers and guidance documents on soil stabilization, ground improvement, and earth reinforcement. During the 1960's and early 1970's he served as the NASA Principal Investigator for the Soil Mechanics Experiment, which was a part of Apollo Missions 14-17 to the Moon.

Dr. Mitchell serves as a consultant on geotechnical problems and earthwork projects of many types, especially soil stabilization, ground improvement for seismic risk mitigation, earthwork construction, and environmental geotechnology, to numerous governmental and private organizations, both nationally and internationally. Recent and currently active projects include the evaluation of seismic stabilities and design of liquefaction mitigation options for Success Dam in California (U.S. Army Corps of Engineers) and Pineview and Deer Creek Dams in Utah (U.S. Bureau of Reclamation), peer reviewer for geotechnical design and construction issues in the proposed depressed Reno Rail Corridor (Kleinfelder), ground improvement aspects of the Port of Oakland Wharf and Embankment Strengthening Program (Harding Lawson Associates), ground improvement and fill stabilization for the proposed San Francisco Airport Expansion (Fugro West), design review – ground improvement for the I-95/Rt.1 Interchange section of the Woodrow Wilson Bridge replacement project (Haley & Aldrich, Virginia Geotechncial Services, URS, HNTB), and Design Review Board for the Third Runway at Seattle-Tacoma International Airport.

He is licensed as a Civil Engineer and as a Geotechnical Engineer in California, and as a Professional Engineer in Virginia. He is a Fellow and Honorary Member of the American Society of Civil Engineers. He served as Secretary (1966-69), Vice-Chairman (1970), and Chairman (1971) of the Geotechnical Engineering Division of ASCE and as Chairman of the United States National Committee for the International Society for Soil Mechanics and Foundation Engineering. He was Chairman of the ASCE Committee on Soil Properties and Chairman of the Committee on Placement and Improvement of Soils, as well as a member of the Environmental Geotechnics Committee. He served as President of the San Francisco Section of ASCE and Chairman of the California State Council of ASCE during 1986-87. He was Chairman of the Transportation Research Board Committee on Physico-Chemical Phenomena in Soils from 1966-1973, and was a member of the TRB Executive Committee from 1983-1987. He was Chairman of the Geotechnical Board of the U.S. National Research Council from 1990 through 1994. He recently completed service as Vice Chair of a NRC study committee for development of science needs for remediation of contaminated Department of Energy weapons sites. He now is a member of a NRC study committee to advise the Department of Energy on Remediation Science and Technology for the Hanford Site. He was Vice President of the International Society for Soil Mechanics and Foundation Engineering from 1989-1994.

Dr. Mitchell was awarded the Norman Medal in 1972 and 1995, the Thomas A. Middlebrooks Award (three times), the Walter L. Huber Research Prize and the Karl Terzaghi Award, all from the American Society of Civil Engineers; the Distinguished Teaching Award and the Berkeley Citation from the University of California; the Western Electric Fund Award of the American Society for Engineering Education; the Medal for Exceptional Scientific Achievement from the National Aeronautics and Space Administration, and has been selected as the recipient of the 2001 Kevin Nash Gold Medal of the International Society for Soil Mechanics and Geotechnical Engineering. He was elected to the United States National Academy of Engineering in 1976 and to the U. S. National Academy of Sciences in 1998.

Lists of projects and publications are available on request.

March 2001

I. M. Idriss

Areas of Teaching, Research and Practice

Geotechnical Earthquake Engineering; Soil Mechanics and Foundation Engineering; Earthfill and Rockfill Dam Engineering; Probabilistic Applications to Geotechnical Problems; Numerical Modeling

Education

B.C.E. Civil Engineering, Rensselaer Polytechnic Institute 1958
M.S. Civil Engineering, California Institute of Technology 1959
Ph.D. Civil Engineering, University of California, Berkeley 1966

Registration

Civil Engineer: California, 1969
Geotechnical Engineer: California, 1987

Professional History

University of California, Davis, Department of Civil and Environmental Engineering, Professor of Civil Engineering, 1989 - to date

University of California, Davis, Director, Center for Geotechnical Modeling, 1989 - 1996

Woodward-Clyde Consultants, Senior Consulting Principal and Vice President, Oakland, California, 1987-1989

Woodward-Clyde Consultants, Managing Principal of the Orange County, Los Angeles and Santa Barbara area offices, and Vice President, 1982-1987

Woodward-Clyde Consultants, Project Engineer to Principal, Vice President and Director, Oakland and San Francisco, California, 1969-1982

UCLA, Department of Civil Engineering, Adjunct Professor, 1984-1986

Stanford University, Dept. of Civil Engineering, Consulting Professor, 1978-1982

University of California, Berkeley, Department of Civil Engineering, Lecturer and Research Engineer, 1966-1975

Consultant to several architect-engineers and other firms, 1966-1969

Dames & Moore, Field Engineer to Senior Engineer, 1959-1966; 1968-1969

Moran, Proctor, Meuser & Rutledge, Field Engineer, summer, 1958

HONORS

Distinguished Public Service Award, University of California, Davis, 1999
H. Bolton Seed Medal, ASCE, 1995
Member, US National Academy of Engineering, elected in 1989
Theme Lecture on "Evaluating Seismic Risk in Engineering Practice," XI International Conference on Soil Mechanics and Foundation Engineering, 1985
Norman Medal, ASCE, 1977
Walter L. Huber Civil Engineering Research Prize, ASCE, 1975
Woodward Lecture, Woodward-Clyde Consultants, 1973
J. James Croes Medal, ASCE, 1972
The Thomas A. Middlebrooks Award, ASCE, 1971
Listed in Who's Who in America, since 1978
Listed in Who's Who in Engineering, since 1977
Chi Epsilon (Honorary Member, Rensselaer Polytechnic Institute Chapter)
Tau Beta Pi
Sigma Xi

SPECIAL ASSIGNMENTS

Invited lecturer at various universities in the United States, Central and Latin America, Canada, Japan, and the Middle East (since 1967)

Invited lecturer and state-of the-art speaker at specialty conferences and special courses in the United States, Latin America, Far East, Europe and the Middle East (since 1970)

1999: Member, Review Panel, Seismic Design Criteria for the Cooper River Bridges in Charleston, South Carolina, Parsons Brinckerhoff, New York City.

1998-date: Member, Peer Review Panel for the design of the New East Spans of the San Francisco – Oakland Bay Bridge, California Department of Transportation, Sacramento

1997-date: Member, US Technical Coordination Committee, US-Japan Cooperative Research Program, National Science Foundation

1996-1997: Member, Review Panel for the High Speed Railway Research Project, National Taiwan University, Taipei

1994-1999: Member, Peer Review Panel for the San Francisco-Oakland Bay Bridge and other Toll Bridges in Northern & Southern California, California Department of Transportation, Sacramento

1994-1995: Member, Advisory Panel for OTA Assessment of the 'Federal Efforts to Reduce Earthquake Damage", Office of Technology Assessment, Congress of the United States

1993-2001: Member, Highway Seismic Research Council Technical Group, National Center for Earthquake Engineering Research (NCEER)

1993-1996: Member, Steering Committee, ATC-35 - Program to Transfer USGS Engineering Seismology Research Results to Engineering Design Practice - Applied Technology Council

1992-1996: Member, Project Engineering Panel, ATC-32 - Review and Revision of Caltrans Seismic Design Procedures for Bridges - Applied Technology Council

1992-1995: Member, Ad Hoc Working Group on the Probabilities of Future Large Earthquakes in Southern California, Southern California Earthquake Center, USGS, California Office of Emergency Services & CDMG

1991-1996: Member, Advisory Council, Southern California Earthquake Center, Los Angeles

1991-1994: Member, Blue Ribbon Panel on the Marina Soil Study, Bureau of Engineering, Department of Public Works, City & County of San Francisco

1991-date: Member, Seismic Advisory Board, California Department of Transportation, Sacramento

1990-1999: Chairman, Seismic Research Advisory Panel, California Department of Transportation, Sacramento

1990-date: Member, External Review Panel, United States Geological Survey

1989-date: Member, Consulting Board for Earthquake Analysis for the Division of Safety of Dams, Department of Water Resources, State of California

1989-1995: Member, Board of Directors, California Universities for Research in Earthquake Engineering (CUREe)

1989-1990: Member, Governor's Board of Inquiry to investigate the collapse of the Cypress section of I-880 and the damage to the Bay Bridge during the 17 October, 1989 Loma Prieta earthquake

1989-1991: Member of the Organizing Committee assisting the Port of Los Angeles in holding a Workshop and a Symposium to address geotechnical and earthquake engineering issues for the Port's 2020 Project

1988-1992: Member, State of California Board of Mining and Geology; Chairman: Geohazard Committee of the Board; also Chairman, Ad Hoc Committee on Deterministic / Probabilistic Seismic Hazard Evaluations

1984-1985: Participant, Workshop on Liquefaction, Committee on Earthquake Engineering, National Research Council

1981-1982: Consultant to UNESCO in Paris, France on geotechnical and earthquake engineering issues in the Middle East and North Africa

1981-1982: Member, Seismic Review Panel for the State of California Public Utilities Commission re: LNG Facility at Point Conception.

1974-1979: Structural Division, ASCE; Nuclear Structures and Materials Committee; Chairman, Ad Hoc Group on Soil-Structure Interaction

1974-1977: Member, Subcommittee on Ground Motions and Site Effects, Applied Technology Council

1971-1981: Seismology Committee, Structural Engineers Association of Northern California; Chairman, Soil Structure Interaction Subcommittee, 1971-72 and 1977-79; Chairman, Subcommittee on Sliding and Overturning, 1979-81

1975-1980: Consultant to the International Atomic Energy Agency, Vienna; participated in preparation of IAEA's Safety Guide on "Seismic Analysis and Testing of Nuclear Power Plants"

1970-1976: Consultant to the Government of Italy on nuclear reactor safety related to earthquake effects

Current Teaching and Research

Starting in the spring of 1990, Dr. Idriss has been teaching a course on geotechnical earthquake engineering in the Department of Civil Engineering at the University of California at Davis. Beginning in 1990-1991, he has also been teaching courses on earthfill and rockfill dams, basic soil mechanics and foundation engineering, advanced soil mechanics and foundation engineering and an undergraduate course in statics.

Since joining UC, he has been conducting research related to: characteristics of earthquake ground motions; equivalent linear and nonlinear response of soil deposits during earthquakes; response of earth and rock fill dams and landfills during earthquakes; liquefaction; mitigation and remediation of liquefaction; and ground deformations due to earthquake loading conditions. In addition, he has supervised studies using the centrifuge to: (i) assess the effects of local site conditions on earthquake ground motions; and (ii) examine the extent of remediation needed to mitigate liquefaction at bridge and near-shore sites.

RECENT AND CURRENT CONSULTING ASSIGNMENTS

Dr. Idriss has been, and continues to be, a consultant to several Consulting Engineering Firms, Architect/Engineering Firms, private and public Research Organizations, Owners, and various State and Federal Agencies. The consulting assignments have included:

Earth Dams, Rockfill Dams and Dikes:

Costa Oriental Dikes in Venezuela
Sardis Dam, Mississippi
Eastside Reservoirs and Dams (formerly called Domenigoni Reservoir & Dams), Southern California
O'Neill Forebay, Central California
Devil Canyon Second Afterbay, Southern California
Garvey Reservoir, Southern California
Xiaolangdi Project (Yellow River Hydroelectric Project), China
North Tailings Dam near Salt Lake City, Utah
Dams, Power & Water Distribution Facilities in British Columbia
Los Vaqueros Dam in Contra Costa County, California
Little Dalton, Big Dalton, Santa Anita and Sawpit Debris Dams
Sacramento-San Joaquin Delta Levees
Seven Oaks Dam, Southern California
Tarbela Dam, Pakistan
Prado Dam, Southern California
Lake Almador & Lake Francis Dams, Northern California
Butte Valley Dam, Northern California
Success Dam, Central California
Cleveland & Seymour Falls Dams, British Columbia
Matahina Dam, North Island, New Zealand
Karapiro Dam, North Island, New Zealand
Waitaki Dams, South Island, New Zealand
Lopez Dam, San Luis Obispo, California
Saluda Dam, South Carolina
Pardee Dam, Northern California
New Hogan Dam, Northern California
Santee-Cooper Project, South Carolina
Wateree Dam, North Carolina
Cushman, Wynoochee, Mayfield, & Mossyrock Dams, Washington
Clackamas River Project, Oregon
Claytor Dam, Virginia
Wickiup Dam, Oregon

Industrial Projects:

Getty Fine Arts Center

San Francisco Marina
Treasure Island
Metro Bay Center
Port of Los Angeles
Bayer's Project Site in Taiwan
Third Runway at the Seattle-Tacoma International Airport

Landfill Projects:
Acme Landfill
Ox Mountain Landfill
Pacheco Landfill
Operating Industries Inc. (OII) Landfill
Chiquita Landfill
Edom Landfill
Sunshine Landfill
Elsmere Canyon Landfill

Nuclear Plants and Facilities:
CESSAR (Combustion Engineering Standard Plant)
Long Term Seismic Program (LTSP) for Diablo Canyon
Seismic Margin Assessment – Hatch Plant, Georgia
Seismic Margin Assessment (SMA) Methodology
LOTUNG experimental and analytical study
New Production Reactors
Ground Motion Guidelines at Nuclear Plant Sites
Replacement Tritium Facility (RTF) at Savannah River
IPEEE Geotechnical Review for Limerick Plant
IPEEE Geotechnical Review for Peach Bottom Plant
Defense Waste Processing Facility (DWPF) at Savannah River
In-Tank Precipitation Facility (ITP) at Savannah River
Humboldt Power Plant (Hazard Evaluation & ISFSI)
Prairie Island Nuclear Generating Plant
Diablo Canyon Nuclear Plant (Hazard Evaluation & ISFSI)
Independent Spent Fuel Storage Installation (ISFSI) – Hatch Plant, Georgia
Independent Spent Fuel Storage Installation (ISFSI) – Farley Plant, Alabama

Bridges:
Seismic Vulnerability of Bridges for the Illinois Department of Transportation
Seismic Hazard Evaluation and Site Response for the Benicia and the Carquinez Bridges
Seismic Hazard Evaluation for Bridge Crossings in Southern California

Seismic Hazard Evaluation for Bridge Crossings in Northern California
Liquefaction & Remediation Assessment at the I-5 / Route 56 Interchange in Southern California
I-880 Reconstruction in Oakland
Route 24/580/980 Interchange in Oakland
San Francisco-Oakland Bay Bridge (existing bridge)
Route 8/805 Interchange in San Diego
California State Toll Bridges in the San Francisco Bay Area
California State Toll Bridges in Southern California
New East Span of the San Francisco-Oakland Bay Bridge
Cooper River Bridges, Charleston, South Carolina

Other Projects:
Nonlinear behavior of soils
Geologic Hazards in the Summit Area of the Santa Cruz Mountains
Marina and South of Market Street Liquefaction Study
Watsonville Liquefaction & Remediation Assessment
The King Dome in Seattle
International Arrival Building at JFK in New York
Pacific Telephone Building, Oakland
Bel Marin Keys, Novato, California
Gas Pipeline Earthquake Performance R&D Project
Webster Street & Posey Tunnels, Alameda, California

for:

ABB Combustion Engineering
ABB Impell
Bayer AG
B. C. Hydro
Brookhaven National Laboratory
CDM Federal Programs Corporation
CH2M HILL
City of San Francisco
County of San Luis Obispo, California
Department of Transportation of the State of California
Department of Water Resources of the State of California
Division of Safety of Dams of the State of California
J. M. Duncan
Emcon Associates
Electric Power Research Institute (EPRI)
Electricity Corporation of New Zealand, Ltd (ECNZ)
EQE
Federal Energy Regulatory Commission
Forell / Elsesser Engineers, Inc.

Geomatrix Consultants
Golder Associates
Greater Vancouver Regional District
Harding Lawson Associates
HNTB
Hushmand Associates
King County, State of Washington
Kleinfelder, Inc.
Lawrence Livermore National Laboratory
Miller Pacific Engineering Group
Morrison Knudsen Corporation
Pacific Engineering & Analysis
Pacific Gas & Electric Co.
Parsons Brinckerhoff, New York City
Parsons Brinckerhoff, San Francisco
Port Authority of New York & New Jersey
Port of Los Angeles
Southern Company Services, Inc.
STS Consultants Ltd.
TAMS
Treadwell & Rollo
US Army Corps of Engineers, Los Angeles District
US Army Corps of Engineers, Sacramento District
US Army Corps of Engineers' Waterways Experiment Station
US Bureau of Reclamation
US Department of Energy
VECTRA Technologies, Inc.
Woodward-Clyde Consultants
World Bank
Yellow River Conservancy Commission, China

PRIOR TEACHING, CONSULTING AND RESEARCH EXPERIENCE

Dr. Idriss taught undergraduate courses in soil mechanics and foundation engineering from 1967 until 1970 at the University of California in Berkeley. He also lectured at various seminars and graduate courses dealing with geotechnical earthquake engineering at UC Berkeley, UCLA and the University of Arizona from 1968 through 1975. He taught a graduate course on earthquake engineering at Stanford University from 1978 through 1982 and undergraduate courses in soil mechanics and foundation engineering in 1986 and 1987 at the University of California in Irvine. Dr. Idriss has also taught at special courses on earth- and rock-fill dams, soil dynamics, soil-structure interaction, site response, earthquake ground motions, liquefaction evaluations ... throughout the United States, in Europe, Central and Latin America and Japan from 1970 to-date.

Prior to joining the faculty of the Civil Engineering Department at the University of California in Davis, Dr. Idriss had about 30 years experience in soil mechanics and foundation engineering, with emphasis in geotechnical earthquake engineering during the latter 25 years. He developed or co-developed several analytical and empirical procedures to evaluate liquefaction potential, behavior of soil masses during earthquakes, seismic behavior of earth and rock fill dams (including post-earthquake considerations), and deterministic and probabilistic assessment of earthquake ground motions.

For a period of about 22 years, Dr. Idriss conducted and directed consulting assignments involving geotechnical earthquake engineering studies for earth, rock fill, and tailing dams, nuclear power plant sites, high-rise buildings, offshore platforms, and industrial facilities.

He also conducted and directed applied research studies. From 1973 through 1989, he directed and participated in multi-disciplinary projects for dams (earth, rock fill, tailings and concrete), commercial and industrial facilities, offshore platforms, nuclear power plant and LNG sites, pipelines, and generic multi-disciplinary projects.

From 1970 to 1989, Dr. Idriss conducted and directed geotechnical earthquake engineering studies for over 50 earth, rock fill, and tailing dams in California, Alaska, Alabama, North Carolina, New Mexico, Tennessee, Utah, Mexico, Guatemala, Costa Rica, Colombia, Argentina, Ecuador, Egypt, Morocco, and Algeria; and earthquake engineering studies (including ground motion characterization, assessment of liquefaction potential, evaluation of soil-structure interaction, and cyclic soil characterization) at over 25 nuclear plant sites in the United States, Europe, and the Middle East. Other geotechnical earthquake engineering projects include offshore platforms in California, Alaska, and New Zealand; and waterfront facilities, fossil plants, and hospital and office buildings in California, Idaho, Alaska, New Jersey, Texas, Italy, Puerto Rico, Iran, Guatemala, Nicaragua, Venezuela, Egypt, Saudi Arabia, Lebanon, and other locations.

Applied research and non-site-specific consulting assignments, during the period 1970 to 1989, included:

- o Soil-structure interaction studies for GESSAR and for General Electric's Standard Plant
- o Behavior of marine clay sediment during earthquake loading conditions
- o Behavior of marine clay sediments during wave loading conditions
- o Behavior of soil-pile-structure systems during earthquake
- o Soil-structure interaction studies and correlation with model field tests
- o Offshore Alaska seismic exposure studies
- o Probabilistic and deterministic assessment of ground motions
- o Engineering characterization of earthquake ground motions to develop guide-lines for seismic inputs for nuclear plants
- o Program for assessment and mitigation of earthquake risk in the Arab Region
- o Seismic margin assessment (SMA) methodology
- o Evaluation of the behavior of the Molikpaq due to ice loading conditions

o Development of earthquake ground motions and dynamic soil properties for CESSAR (Combustion Engineering standard nuclear plant)

Multi-disciplinary projects included:

o Proposed Boruca Dam in Costa Rica
o San Onofre Nuclear Generating Station in southern California
o Seismic exposure studies for offshore Alaska
o Proposed offshore platform in southern California
o Bullards Bar Dam in northern California
o Bolsa Chica Development in southern California
o State Office Building in Anchorage, Alaska
o Honda Headquarters in southern California
o Costa Oriental Dikes in Lake Maracaibo Region, Venezuela
o Getty Fine Arts Center in Brentwood, California

He conducted research related to the nonlinear behavior of soils under cyclic loading conditions. The results of this research have been applied to assessing performance of soft sediments during earthquakes. He has been engaged in other research activities that relate to significant duration of earthquakes, simplified procedures for assessment of soil-structure interaction, probabilistic review and assessment of recorded ground motions and associated spectra, and application of probabilistic techniques in geotechnical practice.

AFFILIATIONS

American Society of Civil Engineers
American Society for Engineering Education
Earthquake Engineering Research Institute
California Universities for Research in Earthquake Engineering (CUREe)
Seismological Society of America
Structural Engineers Association of Northern California
U. S. Committee of the International Commission on Large Dams

PUBLICATIONS

Dr. Idriss has authored or co-authored about 150 technical papers and research reports on subjects related to the geotechnical aspects of earthquake engineering (seismic response of soil deposits; earth structures including slopes, earth and rock fill dams; dynamic soil material properties; liquefaction; soil-structure interaction; and probabilistic deterministic assessment of characteristics of ground motions). These papers have been published in the Journals of the Geotechnical Engineering Division, the Structural Engineering Division, and Proceedings of Specialty Conferences of the American Society of Civil Engineers; Bulletin of the Seismological Society of America; International Journal of Earthquake Engineering and Structural Dynamics; proceedings of World Conference on Earthquake Engineering, proceedings of the US National Conference on Earthquake Engineering, proceedings of the

International Conference on Soil Mechanics and Foundation Engineering, proceedings of the Offshore Technology Conference, and proceedings of other international engineering meetings.

Curriculum Vitae

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CITIZENSHIP

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(S.S. No. 239-80-7650)

EDUCATION

Ph.D. (Civil Engineering) - Purdue University, 1993.
M.S. (Civil Engineering) - Northwestern University, 1979.
B.S. (Civil Engineering) - University of North Carolina at Charlotte, 1975.
A.A. (Pre-engineering) - Central Piedmont Community College, 1973.

PROFESSIONAL REGISTRATION

Professional Engineer: Illinois (by Exam), Maryland, Michigan, South Carolina, Georgia and Virginia.

PROFESSIONAL SOCIETIES AND AFFILIATIONS

American Society of Civil Engineers, Member.
American Society for Testing and Materials, Fellow and Vice Chair (past chair) of Committee D35 on Geotextiles, Geomembranes and Related Products.
Geotechnical Institute, Member.
Industrial Fabrics Association International, Past Chairman Technical Committee.
International Geotextile Society, Council Member.
International Society for Soil Mechanics and Foundation Engineers, Member.
International Standards Organization, U.S. Representative.
National Society of Professional Engineers, Member.
North American Geosynthetics Society, Past President.
Transportation Research Board, Subcommittee Co-chair.

EXPERIENCE

1994-Present Geo-engineering Consultant - Independent geotechnical engineer with specialization in: reinforced soil and other ground improvement technologies; geo-environmental containment system design, geosynthetics application and design; geotechnical and geosynthetics laboratory testing; insitu measurements; and field instrumentation. Currently co-principal of the FHWA "Geosynthetics Design and Construction Workshop," the FHWA "Ground Improvement Technologies Workshop" and the HITEC program on evaluation of earth retaining systems.

1989-1994 Vice President Technical Services - Polyfelt Americas. Responsible for applications engineering, Research and Development, and product quality assurance for worldwide manufacturer of geotextiles. Consulted with users, owners and agencies on geosynthetic design for waste containment and earth structures applications.

1978-1989 Principal Engineer (last position held) - STS Consultants, Ltd. Responsible for design and technical review of geotechnical projects as well as direction and technical evaluation for all STS geotechnical laboratories. Specialty consulting for projects involving geotextile and geomembrane application, geosynthetic evaluation, earth retention system design, reinforced soil design, geo-environmental containment systems, insitu instrumentation and geophysical evaluation. Set up and managed STS Geotechnical and Geosynthetic Testing Center in Northbrook, IL, the first independent geosynthetic research and development laboratory in North America. Served as Regional Office Manager for Washington D.C./Virginia operation (1981-82) including project review, laboratory development, geotextile consulting, and client contact. In 1980 served as special project manager for the Foreign Trade Center in Bejing, China.

1977-1978 Research Engineer, Northwestern University. Responsible for preparation of test procedures, testing, analysis of data and presentation for research projects on grouted soils and scrubber sludges.

1973-1975 Engineering Technician, Law Engineering Testing Company. Laboratory testing and field inspection.

PUBLICATIONS

Dr. Christopher has published over 70 technical papers including three design manuals on geosynthetics for the Federal Highway Administration (FHWA), two FHWA design manuals on soil reinforcement, a geosynthetics design manual for the American Society of Dam Safety Officials, a textbook on geosynthetics, a chapter on geosynthetics in a groundwater engineering handbook, and recently a National Cooperative Highway Research Program Synthesis on *Pavement Subsurface Drainage Systems*. He has given many presentations and short courses including numerous FHWA "Geosynthetic Engineering Workshops", FHWA "Mechanically Stabilized Earth Walls and Reinforced Soil Slope Workshops", and NICET training courses on geosynthetics in waste containment.

LIST OF PUBLICATIONS

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Borden, R., Christopher, B.R., Krizek, R.J., Characterization of SO_2 Scrubber Sludge", Journal of Construction Engineering, Vol. I, ASCE, 1979.

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Christopher, B.R., "Geotextiles in Landfill Closures", Geotextiles and Geomembranes, Vol 10, Nos 5-6, Elsevier, 1991, pp. 459-470.

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Christopher, B.R., "Geotextiles in Filtration Application", GeoHorizon - State of Art in Geosynthetics Technology, Oxford & IBH Publishing Co., New Delhi, India, 1997, pp. 53 - 68.

Christopher, B.R. and McGuffey, V.C., Pavement Subsurface Drainage Systems, National Cooperative Highway Research Program, Synthesis of Highway Practice 239, Transportation Research Board, National Academy Press, Washington, D.C., 1997, 44 p.

Holtz, R.D., Christopher, B.R. and Berg, R.R., Geosynthetic Engineering, BiTech Publishers Ltd., Richmond, British Columbia, Canada, 1997, 452 p.

Zornberg. J.G. and Christopher, B.R., "Geosynthetics", The Handbook of Groundwater Engineering, Chapter 27, Deleur, J.W. Editor, CRC Press, 1998, pp. 27-1 - 27-31.

Christopher, B.R., Zornberg, J.G. and Mitchell, J.K., "Design Guidance for Reinforced Soil Structures with Marginal Soil Backfills", Proceedings of the Sixth International Conference on Geosynthetics, Atlanta, March 1998, pp. 797-804.

Christopher, B.R., "The First Step in Geotextile Filter Design," Geotechnical Fabrics Report, Vol. 16, No. 2, Industrial Fabrics Association International, March 1998.

Hayden, S.A., Christopher, B.R., Humphrey, D.N., Fetten, C.P. and Dunn, P.A., Jr., "Instrumentation of Reinforcement, Separation and Drainage Geosynthetic Test Sections used in the Reconstruction of a Highway in Maine", Proceedings of the 9th International Conference on Cold Regions Engineering, Duluth, MN, September 1998, pp.420-433.

Christopher, B.R., "Performance of Drainable Pavement Systems: A U.S. Perspective", International Symposium on Subdrainage in Pavements and Subgrades, Granada, Spain, PIARC, November, 1998.

Hayden, S.A., Humphrey, D.N., Christopher, B.R., Henry, K.S., and Fetten, C.P., "Effectiveness of Geosynthetics for Roadway Construction in Cold Regions: Results of a Multi-Use Test Section," Proceedings of Geosynthetics '99, Vol. 2, Boston, Massachusetts, March 1999, pp.847-862.

Christopher, B.R., Hayden, S.A., and Zhao, A., 1999. "Roadway Base and Subgrade Geocomposite Drainage Layers," *Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390*, J.S. Baldwin and L.D. Suits, Eds., American Society for Testing and Materials, West Conshohocken, PA.

Christopher, B.R. and Stulgis, R.P., AThe Future of Geosynthetics: Mechanically Stabilized Earth (Mse) Walls,@ Geosynthetics in the Future: Year 2000 and Beyond, GRI Conference Series GRI-13, Koerner, R.M., Koerner, G.R., Hsuan, Y. and MarilynV. Ashley, Editors, Geosynthetic Institute, Folsom, PA, 1999, pp.172 – 182

Christopher, B.R., Maintenance of Highway Edgedrains, National Cooperative Highway Research Program, Synthesis of Highway Practice 285, Transportation Research Board, National Academy Press, Washington, D.C., 2000, 62 p.

Berg, R.B., Christopher, B. R. and Perkins, S., Geosynthetic Reinforcement of the Aggregate Base/Subbase Courses of Pavement Structures, prepared for American Association of Highway and Transportation Officials Committee 4E, Prepared by the Geosynthetic Materials Association, 2000, 176 p.

REPRESENTATIVE RESEARCH AND SPECIALTY CONSULTING PROJECTS

"Instrumentation of Geotextiles in two Pavement Sections in New Orleans" for Carthage Mills in cooperation with the City of New Orleans and Tulane University, 1979.

"Geotextile Engineering Workshop" for the Federal Highway Administration, 1983 - 1987.

"Load Transfer Instrumentation of a Caisson for High Capacity Load Tests" for STS Consultants, Ltd., four projects 1982 - 1987.

"Lateral Flow through Needle-punched Nonwoven Geotextiles" for Hoechst-Celanese, 1983.

"Behavior of Reinforced Soil" for the Federal Highway Administration, 1984 - 1989.

"Dredge Spoil Stabilization using Geosynthetic Reinforcement: Seagirt Marine Terminal" for Lyons and Associates, 1983 - 1984.

"Geotextile Drainage and Filtration Design Manual" for Phillips Fibers Company, 1985.

"Geotextile Reinforced Embankment for support of a Four Lane Divided Highway over a Peat Bog" for J.C Zimmerman Engineering Corporation and the Wisconsin Department of Transportation, 1986 - 1987.

"Instrumentation of Reinforced Soil Wall at the Cascade Dam" for the Signode Corporation and STS Consultants, Ltd., 1987.

"Geogrid Reinforced Soil Wall Design Manual" for the Signode Corporation, 1987.

"Nodal Load Transfer of Geogrids During Pullout" for the Signode Corporation, 1987 - 1988.

"Seismic evaluation of a Reinforced Soil A-Symetrical Coal Storage Facility in Wasco, California" for Reinforced Earth Company, 1987.

"Reinforced Soil Test Embankments to evaluate Geogrids and Geotextiles for Extension of Mine Tailings Dam" for Hibbing- Tyconite, 1987 - 1988.

"Lateral Flow Characteristics of ICE Prefabricated Drains" for International Construction Equipment, 1987 - 1988.

"Mechanical and Hydraulic Characterization of Geosynthetic Clay Liners (Enviromat)@ for Industrial Minerals Corporation, 1987 - 1988.

"Geotextile Implementation and Guidelines Manual" for the Federal Highway Administration through contract with GeoServices, 1987 - 1988.

"Lateral Flow Characteristics of Dow Chemical Prefabricated Drains" for Dow Chemical Corporation in cooperation with Purdue University, 1988 - 1989.

"Design, Instrumentation and Construction of a Full Scale Geogrid Reinforced Soil Test Wall" for Mirafi, Inc., 1988 - 1989.

"Instrumentation of a 40-Ft. High Geotextile Wall in Seattle, Washington" for the Washington Department of Transportation, 1988 -1989.

"Design and Instrumentation of Reinforced Soil Cement Arch to Increase Tunnel Radiation Shielding" for Brookhaven National Laboratories, 1989.

"Reinforced Soil Test Embankment Over Lime Sludge Lagoon" for the City of Columbus, Ohio and Ohio DOT, 1989 - 1990.

"Geosynthetics in Dams - Design Guidelines and Training" for the Association of State Dam Safety Officials, 1989.

"Designing with Geosynthetics - Training" for the Soil Conservation Services, 1991.

"Reinforced Soil Slopes Computer Program Development" for Federal Highway Administration, peer reviewer and advisor through contract with Earth Engineering and Sciences, Inc., 1990 through 1997.

"Durability of Geosynthetics" for Federal Highway Administration, Advisory team, 1991 through present.

"Manual and Workshops on Ground Improvement Technologies" for Federal Highway Administration, co-principal on MSE structures section through contract with Earth Engineering and Sciences, Inc., 1993 through present.

"Technical Advisor for the Design and Instrumentation of 6 meter high Reinforced Embankment over highly plastic bay, soft muds at the Thessalonika Harbor in Greece" for Geomechanici, 1992-1996.

"Technical advisor for the design, instrumentation and construction of three full scale reinforced embankments constructed to failure using high-strength geocomposites, multiple layers of geotextiles and a control section, respectively," for the Polyfelt Reseach Embankment Project in Bangkok, Thailand, 1993.

"Geosynthetics Engineering Workshops" for Federal Highway Administration, co-author of manual and co-principal lecturer, through contract with Ryan Berg and Associates, inc., 1993 through present.

"Technical Design Advisor and Instrumentation of a 50 ft high, Geotextile Reinforced Soil Slope" for Federal Highway Administration, Western Lands Division, 1993-1994.

"Peer Review of the Geomembrane Liner Protection System and Geonet design for the 150 m deep, Went Landfill, Hong Kong" for Polyfelt Americas and Browning Ferris Industries, 1994.

"Peer Review of Stability Analysis of Steep Side Slopes at the Nent Landfill, Hong Kong" for Far East Landfill Technologies, Ltd., 1994-1995.

"Instructor for NICET Certification Training Course for Construction Quality Control and Quality Assurance in Landfill Applications" 4 one-week courses: AGP Laboratories, 1995.

"Earth Retaining Systems Evaluation" (review of proprietary reinforced soil wall systems) for HITEC/CERF, 1996 through present.

"Soil Nailing Project for retaining wall replacement on N.H. Route 112 (Kancamagus Highway)" Consultation on Design, Instrumentation and Construction Consultation for Haley & Aldrich.

"Reinforced Fill Procurement Evaluation" for the Hong Kong Government, 1997-1999.

"Technical Advisor for the Instrumentation of a Reinforced Flood Control Dyke" for the US Army Corps of Engineers in cooperation with the Louisiana Transportation Research Center, 1996-1997.
"Technical Advisor for the Design and Instrumentation of Reinforced Slopes constructed with highly Plastic Soils" for the Louisiana Transportation Research Center in cooperation with the Federal Highway Administration, 1997-1998.

"Technical Advisor for the Design and Instrumentation of Reinforced Slopes constructed with Marginal Soils at the ALF Test Site" for the Louisiana Transportation Research Center in cooperation with the Federal Highway Administration, 1997-1998.

"Facilitator for a European Scan Tour to evaluate implementation of LRFD and Alternative Contracting@ for the Federal Highway Administration , 1997-1998.

"Technical Advisor for the Design and Instrumentation of a multi-use roadway test sections to evaluate geogrid and geotextile reinforcement, geotextile separation and geocomposite drainage geosynthetics for reconstruction of a highway in Maine" for the Maine DOT in cooperation with the U.S. Army Cold Regions Research Laboratory and the University of Maine, 1997-present. Special focus was on the geosynthetic composite drainage sections for the Tenax Corporation.

"Technical Advisor for the Design and Instrumentation of a multi-use roadway test sections to evaluate geogrid and geotextile reinforcement, geotextile separation and geocomposite drainage geosynthetics for reconstruction of a highway in Wisconsin" for the University of Wisconsin Special focus was on the geosynthetic composite drainage sections for the Tenax Corporation.- On-going.

Co-Principal of National Cooperative Research Synthesis Project 20-7, Task 112 on "Geosynthetic Reinforcement in Roadway Sections – On-going.

PETER M. DOUGLASS, P.E.
Geotechnical Engineering Consultant
Specializing in Tunnels & Underground Construction

EDUCATION

M.S. Civil Engineering
(Geotechnical), 1975
University of Illinois
M.S. Geology
(Rock Mechanics), 1968
Pennsylvania State University
B.A. Geology, 1965
Antioch College

PROFESSIONAL REGISTRATION

Professional Engineer
State of Washington
Professional Geologist
State of Oregon
Engineering Geologist
State of Oregon

PROFESSIONAL SOCIETIES

Dispute Review Board Foundation (Officer '97-'98)
Underground Technology Research Council (Past Chairman)
American Society of Civil Engineers
(Past Chairman, Seattle Geotechnical Group)
American Underground-Space Association
Association of Engineering Geologists
International Society for Rock Mechanics

PROFESSIONAL EXPERIENCE

1992 to Present - Peter M. Douglass, Inc., Seattle, WA.
& 1989 to 1990 Independent Geotechnical Consultant
(specializing in tunnels and underground construction).

1990 to 1992 - Woodward-Clyde Consultants, Seattle, WA.
Vice President, Senior Consultant and Director of Geotechnical Services for the Pacific Northwest.

1979 to 1989 - Hart Crowser, Inc., Seattle, WA and Anchorage, AK.
Vice President and Senior Principal Engineer with this Seattle-based geotechnical and environmental consulting firm. Responsible for their tunneling, mining and rock mechanics work, and other major projects.

1968 to 1979 - Shannon and Wilson, Inc., Seattle, WA.
Staff Engineer to Principal Engineer in charge of their tunneling, instrumentation, and rock mechanics group.

Over the past 30 years, Mr. Douglass has had responsible involvement in numerous Seattle and Puget Sound area projects including over 15 western Washington tunnel projects and more than 40 national and international tunnel projects. His responsibilities on tunnel projects have included geotechnical engineering for feasibility, design and construction of soil and rock tunnels ranging from 6 to 65 feet in diameter. He has provided evaluation and design of tunnel, shaft, and underground chamber support and final linings; developed and assisted in monitoring grouting programs for new and existing tunnels; assisted in the determination of dewatering requirements, design of dewatering systems, groundwater monitoring and groundwater control during tunnel and shaft construction; provided assessments of tunneling ground behavior under a variety of subsurface conditions and excavation methods and equipment; designed, installed, monitored and evaluated instrumentation systems for determining ground movements and load transfer associated with tunnel construction; assisted in the monitoring and evaluation of ground vibrations and their impacts on existing surface and underground facilities; assisted in the preparation of cost estimates for tunnel construction; been responsible for preparation of final plans and specifications for tunnel and shaft construction projects; assisted in the administration of tunnel construction contracts and resolution of Owner/Contractor disputes without litigation; worked as expert witness on tunnel construction claims litigation; and has actively participated in the development and implementation of improved contracting practices in tunneling such as Geotechnical Baseline Reports (GBR) and Dispute Review Boards (DRB).

REPRESENTATIVE PROJECT EXPERIENCE

- South Fork Tolt River Intake Tower Seismic Upgrade, Seattle Public Utilities. Chairman of the Dispute Review Board for the seismic upgrade of the existing intake tower involving installation of tie-down tendons each stressed to over 2,000 kips.

- Second Manapouri Tailrace Tunnel (2MTT), New Zealand. Owner appointed Dispute Review Board member for this 5.6 mile long, 30-foot diameter rock tunnel, shafts, adits and connection to the existing draft tube manifold.

- Alki Transfer/CSO Project, West Seattle Tunnel, Seattle, WA. Performed geotechnical pre-bid evaluation for contractor bidding this roughly 2-mile long interceptor sewer tunnel in glacially overconsolidated soils.

- Vermont/Santa Monica Station and Crossover, Los Angeles Metro Rail Transit, Los Angeles, CA. Disputes Review Board chairman on this Metro Red Line cut and cover transit tunnel station in soils and rock.

- Hollywood/Western Station and Crossover, Los Angeles Metro Rail Transit, Los Angeles, CA. Disputes Review Board chairman on this Metro Red Line cut and cover transit tunnel station.

- Vermont/Hollywood Tunnel, Los Angeles Metro Rail Transit, Los Angeles, CA. Disputes Review Board chairman on this Metro Red Line Segment 2 tunnel project involving construction of over 12 miles of 18-foot I.D. shield driven soil and rock tunnels, excavated from 4 simultaneous headings originating from one central shaft.

- Galer Street Tunnel Collapse, Seattle, WA. Expert Witness for the tunneling subcontractor on this jacked pipe tunnel project in which the Contractor's Job Superintendent lost his life in the collapse of a bulkhead at the heading.

- Access Shaft to Metro Brick Lined Sewer, Seattle, WA. Special consultant to design team for permanent 90-foot deep access shaft connecting to existing brick lined sewer in glacially overconsolidated soils. Connection had to be made without interrupting service of the brick lined sewer.

- Fort Lawton Tunnel Project, Seattle, WA. Performed geotechnical pre-bid evaluation for the successful contractor on this interceptor sewer tunnel in glacially overconsolidated soils.

- Bay Freeway Project, Seattle, WA. Responsible for geotechnical investigations and design recommendations for this proposed elevated freeway along the south end of Lake Union to connect I-5 with the Seattle Center. Project included numerous borings and pile load tests through thick sawdust deposits.

- Central Quadrangle Project, University of Washington, Seattle, WA. Responsible for geotechnical investigations, design recommendations and geotechnical services during construction of this major underground parking garage, adjacent University building and underground connections to existing structures.

- Sealand Pier, Port of Tacoma, Tacoma, WA. Responsible for geotechnical investigations, design recommendations and geotechnical services during construction of this major pier development project including the largest traveling container cranes on the West Coast at the time.

- Chambers Creek Interceptor Tunnel, Pierce County, WA. Geotechnical project manager for this 2.5-mile, 100-foot-deep soft ground tunnel through glacially overridden silts, sands and gravels. Services included assessment of subsurface conditions, tunneling ground behavior, excavation and support methods and dewatering requirements. Assisted in the preparation of contract documents; provided on-call tunnel consulting services during construction; participated in Disputes Review Board meetings with the Contractor and engineer; and assisted in disputes resolution. Project was completed ahead of schedule at a final cost 30 percent below the Engineer's Estimate.

- Cedar River Pipeline Relocation, Seattle, WA. Provided geotechnical investigations, design recommendations and on-call tunnel consulting services during construction of the 90-foot-deep shaft and 600-foot-long, 12-foot-diameter tunnel in glacially overconsolidated hard silts and clays near Dearborn Street for relocation of a high pressure water supply line beneath I-90.

- Mount Baker Ridge Highway Tunnel, Seattle, WA. Involved in various stages of the design and construction of this 65-foot-diameter soft ground tunnel.

  - Involved in the geotechnical investigations, tunnel engineering and served for two years as the Project Geotechnical Engineer on the tunnel. Also selected to act as Principal Investigator on a major federal research project at the tunnel site to evaluate state-of-the-art soft ground tunnel exploration methods (this research was later canceled when the tunnel construction was delayed).

  - Principal-in-charge of geotechnical engineering for the cut and cover section of I-90 west of the tunnel, the ventilation building at the west portal and the new ventilation shafts connecting to the existing twin tunnels.

- North Operating Base Tunnel under I-5, Seattle, WA. Development of preliminary concepts to construct a bus access tunnel at shallow depth below I-5 at the Metro North Operating Base.

- South Hanford Street and Bayview Tunnels, Seattle, WA. Review of the condition of the existing South Hanford Street and Bayview tunnels which led to rehabilitation and tunnel lining modifications which separated sanitary and storm water flows.

- North Cascade Highway Tunnel, Western WA. Detailed mapping of joints and shear zones and development of rock bolt and concrete liner design to resolve rockfall problems in this previously unlined highway tunnel.

- River Mountain Pumped Storage Project, Arkansas. Provided geotechnical overview services for the owner during the license application and design team selection for this proposed 600 MW hydroelectric project involving 30-foot diameter intake/outlet shaft and pressure tunnel roughly 700 feet below ground surface, an underground powerhouse chamber, a 1-mile long 40-foot diameter tailrace tunnel and 1/2-mile long 40-foot diameter access tunnel, all in shale and sandstone.

- Lake Whatcom Water Supply Tunnel, Bellingham, WA. Performed inspection of existing concrete tunnel lining condition in this 8-foot horse-shoe pressure tunnel constructed in rock over thirty years ago.

- Twin Falls Hydroelectric Power Project, North Bend, WA. Principal-in-charge of geotechnical investigations, alignment studies, and assessment of tunnel excavation and support requirements for this proposed 4,100-foot-long, 8-foot-diameter tunnel beneath I-90 and a 320-foot-deep, 8-foot-diameter intake shaft. Although the selected alignment was predominantly in rock, initial studies also investigated a possible alignment with the tunnel predominantly in glacially overridden sands and gravels.

- Mud Mountain Dam Intake Modifications, Buckley, WA. Principal-in-charge of geotechnical investigations and design of excavations and support for 90-foot-deep rock cuts, turn-under chamber, and tunnels in conjunction with new intake structure at the existing Mud Mountain Dam. Project elements included an underground chamber, tunnels ranging from 9 to 23 feet in diameter, and transitions to existing tunnels at depths in excess of 300 feet in faulted and deformed volcanic rocks.

- Eklutna Lake Diversion, Anchorage, AK. Project Manager for all final design A/E services for this 1.5 mile, 6-foot I.D. pressurized water supply tunnel project, including a 160-foot-deep, 22-foot-diameter intake valve shaft and permanent connection to an existing 9-foot I.D. power tunnel. Services involved geotechnical investigations, assessment of dewatering requirements, tunneling ground behavior, excavation methods, permanent lining design, grouting criteria and grout monitoring for new and existing tunnels, preparation of plans and specifications, assistance in preparing Engineer's Estimate, review of Contractor submittals, construction interaction including review of daily field reports and regular site visits, and assistance in resolution of owner/contractor disputes. Mr. Douglass relocated to Anchorage for approximately one year during the design phase of this soft ground tunnel project (in glacially overridden silts, clays, sands and gravels) and opened Hart Crowser's Anchorage office.

- The Seattle Times Building, Bothell, WA. Responsible for geotechnical services during construction of this state of the art newspaper printing and distribution facility including heavily loaded settlement sensitive printing presses (1/4 - inch differential settlement tolerance).

- SR-18 Roadway Widening Project, North Bend to Auburn, WA. Responsible for geotechnical investigations and design input for this major highway widening project through mountainous terrain involving major slope instability considerations, major soil and rock cuts, 60-foot high embankments, bridges and interchanges.

- Richmond Transport Tunnel, San Francisco, CA. Senior consultant providing in-house peer review and consultation on this 14-foot diameter, 2 mile long soil and hard rock tunnel to minimize possible wastewater overflows into San Francisco Bay. The project included an underground overflow chamber and connection to an abandoned tunnel outfall to provide additional storage.

- Elk Creek Highway Tunnel Project, Elkton, OR. Senior engineer involved in assessing tunnel widening/replacement options for an existing 1200 foot long, 20 foot wide rock tunnel.

- Down-river Transfer/Storage Tunnel Project, Detroit, MI. Retained by design team to provide independent review of Geotechnical Baseline Reports (GBR-previously referred to as GDSR) for three (3) 10-foot diameter soft ground tunnels, each 12 to 15 kilometers in length, and one pump station during preparation of final contract documents.

- Inter-Island Tunnel, Boston Harbor Project, Boston, MA. Disputes Review Board chairman on this 5 mile, 11.5-ft finished diameter sewer tunnel beneath the Boston Harbor.

- CSO Control Retention Treatment Tunnel, City of Dearborn, MI. Chairman of Disputes Review Board for this 2-mile long, 18-foot finished diameter rock tunnel with associated shafts and collection/control structures.

- Muck Valley Hydroelectric Project, Northern California. Reconnaissance and preliminary geotechnical engineering studies, design recommendations and on-call tunnel consulting services during construction of this 4.1-mile-long, 12-foot diameter tunnel in volcanic deposits. The project was constructed with the final alignment and grade essentially the same as presented in the preliminary engineering studies. A specially designed Tunnel Boring Machine (TBM) was used to drive the tunnel in these complex volcanic deposits with average advance rates of 8 to 10 feet per hour. Mr. Douglass was requested to serve as the owner's representative on a 3-man claims resolution board on this project.

- Howard Hanson Dam Hydroelectric Project, WA. Reconnaissance and preliminary engineering assessment for proposed 1,000-foot-long tunnel through the right abutment of the existing Howard Hanson Dam.

- Pumped Storage Hydroelectric Projects, WA and CA. Reconnaissance and preliminary engineering assessment for proposed 750 to 1500 MGW pumped storage projects involving 0.5 to 3 mile long pressure tunnels to 30 feet diameter, underground powerhouses, and access tunnels.

- Mud Mountain Hydroelectric Project, WA. Reconnaissance and preliminary engineering assessment for an underground powerhouse and tunnel connecting with an existing 23-foot-diameter discharge tunnel in volcanic rocks.

- Summer Falls Hydroelectric Project, Grant County, WA. Geotechnical investigations and preliminary design studies and engineering recommendations for twin 17-foot-diameter tunnels constructed in basalt.

- Superconducting Super Collider, Construction of S40 to S55 Tunnel (Basic), Waxahatchee, TX. Selected as Disputes Review Board chairman on this segment of the SSC project involving construction of 44,000 feet of tunnel and several shafts in Austin Chalk.

- Table Tunnel West, British Columbia, Canada. Retained by contractor as expert witness on claims for this major railroad tunnel through hard rock.

- Old Man River Dam-Diversion Tunnels, Pincher Creek, Alberta, Canada. Special consultant to assess the cause of poor progress on twin 23-foot-diameter rock tunnels being advanced by drill and blast methods. Provided recommendations for modifications and conflict resolution for contractor.

- Owyhee Dam Tunnel No. 1, Malheur County, OR. Investigations to assess the feasibility and required remedial work to pressurize a 3.5-mile-long, 17-foot-diameter existing irrigation tunnel, with an unreinforced concrete lining, in volcanic rocks. Services included exploration borings through the existing lining, a test grout injection program, and preliminary cost estimates for contact grouting outside the entire existing lining.

- Quartz Hill Mine Highway Tunnels, Southeast AK. Reconnaissance and geotechnical engineering feasibility studies for three highway tunnels through steep mountainous terrain within the Misty Fjords National Monument.

- Southeast Relieving Interceptor, Phase 3 Tunnel Project, Portland, OR. Provided assessment of dewatering requirements during design of this sanitary tunnel project in glacially overridden silts, sands and gravels. High transmissivities of sand and gravel deposits, combined with limited surface discharge capacity in this urban area, required reliable prediction of dewatering quantities to develop a reasonable tunnel excavation/dewatering sequence for construction.

- Mount Carmel Highway Tunnel, Zion National Park, UT. Site investigations and instrumentation to assess unique stability conditions associated with large ventilation galleries daylighting from the existing tunnel to a 600-foot-high cliff face of Navajo sandstone.

- Vat Tunnel, Strawberry Aqueduct, Wasatch County, UT. Assisted in pre-bid geotechnical evaluation for contractor on this 7.3-mile-long, 8-foot I.D. water supply tunnel through complex sedimentary rock with potential high groundwater inflows and squeezing ground.

- Railroad Tunnel Monitoring, Bozeman Pass, MT. Monitored vibrations and crack deformations in existing railroad tunnel during blasting for a new highway cut above and immediately adjacent to the mainline railroad tunnel.

- Mount Adams Anchorage Tunnel, Cincinnati, OH. Geotechnical investigations and engineering design and construction recommendations for an 8-foot-diameter, 1,200-foot-long tieback anchorage tunnel constructed beneath an urban area of Cincinnati. Lining design required consideration of eccentric loads applied by anchor blocks installed along one side of the tunnel and connected to 800-ton design load tieback tendons for a massive cylinder pile retaining wall.

- Cross-Irondequoit Interceptor Tunnel, Rochester, NY. Installed, monitored and interpreted results of MPBX instrumentation system to assess ground movements associated with construction of an 18-foot-diameter machine bored tunnel in an urban area of Rochester.

PUBLICATIONS AND PRESENTATIONS

"Geotechnical Baseline Reports for Underground Construction" by the Technical Committee on Geotechnical Reports of the Underground Technology Research Council (UTRC) (P.M. Douglass served on UTRC Technical Committee, DRB Member's Perspective panel and final editorial review committee), ASCE Booklet Publication, 1997.

"Avoiding and Resolving Disputes in Underground Construction" by the Contracting Practices Committee (P.M. Douglass - Chairman) of the Underground Technology Research Council (UTRC), ASCE Booklet Publication, 1989.

"Design of PCCP Pressure Tunnel Liners" by P.M. Douglass, C.C. Sundberg, R.E. Heuer and S. Paul. 1987 Rapid Excavation and Tunneling Proceedings - AIME and ASCE, pp. 63-86.

"Geotechnical Investigations for Construction Dewatering for Soft Ground Tunneling" by R.E. Heuer and P.M. Douglass. The Art and Science of Geotechnical Engineering at the Turn of the Century, a Symposium honoring Dr. Ralph B. Peck, University of Illinois, April 1986.

"Groundwater Problems in Soft Ground Tunneling" by R.E. Heuer and P.M. Douglass. Presented by P.M. Douglass at the Geotech IV Conference in Boston, October 1986 - ASCE.

"Chambers Creek Interceptor Sewer Tunnel" by P.M. Douglass, M.J. Bailey, and J.J. Wagner. Rapid Excavation and Tunneling Conference, June 1985 - AIME and ASCE.

"Nature and Mechanics of the Mount St. Helens Rockslide-Avalanche of May 18, 1980" by B. Voight, R.J. Janda, H. Glicken and P.M. Douglass, 1983, Geotechnique, Vol. 33, pp. 243-273.

"Evaluation of Surface Coal Mine Spoil Pile Failures" by P.M. Douglass and M.J. Bailey, Third International Conference on Stability in Surface Mining, Vancouver, B.C., June 1981.

"Catastrophic Rockslide Avalanche of May 18, The 1980 Eruptions of Mt. St. Helens, Washington" by B. Voight, H. Glicken, R.J. Janda, and P.M. Douglass, USGS Professional paper 1250, 1981.

"Geotechnical Engineering Applied to the Strip Mining Industry" by P.M. Douglass, paper presented at the 81st Annual Convention of the Northwest Mining Association, Spokane, Washington, 1975.

"Slope Stability Problems at Mayfield Dam" by P.M. Douglass.

Rock Mechanics: The American Northwest, International Society of Rock Mechanics, 3rd Congress Expedition Guide, 1974.

"Field Testing with the Goodman Borehole Jack" by R.P. Miller, P.M. Douglass and T.G. Bumala, paper presented at the American Society of Testing and Materials Symposium on Field Testing and Instrumentation of Rock, Philadelphia, Pennsylvania, 1973.

"Antisotropy of Granites: A Reflection of Microscopic Fabric" by P.M. Douglass and B. Voight, Geotechnique, The Institute of Civil Engineers, London, Volume 19, No. 3, September 1969, pp. 376-390.

HONORS AND AWARDS

1984 Case Histories Award, presented by the U.S. National Committee for Rock Mechanics.

George Stephenson Gold Medal 1984, presented by the Institution of Civil Engineers, England.

E

Example Cross Section for West MSE Wall

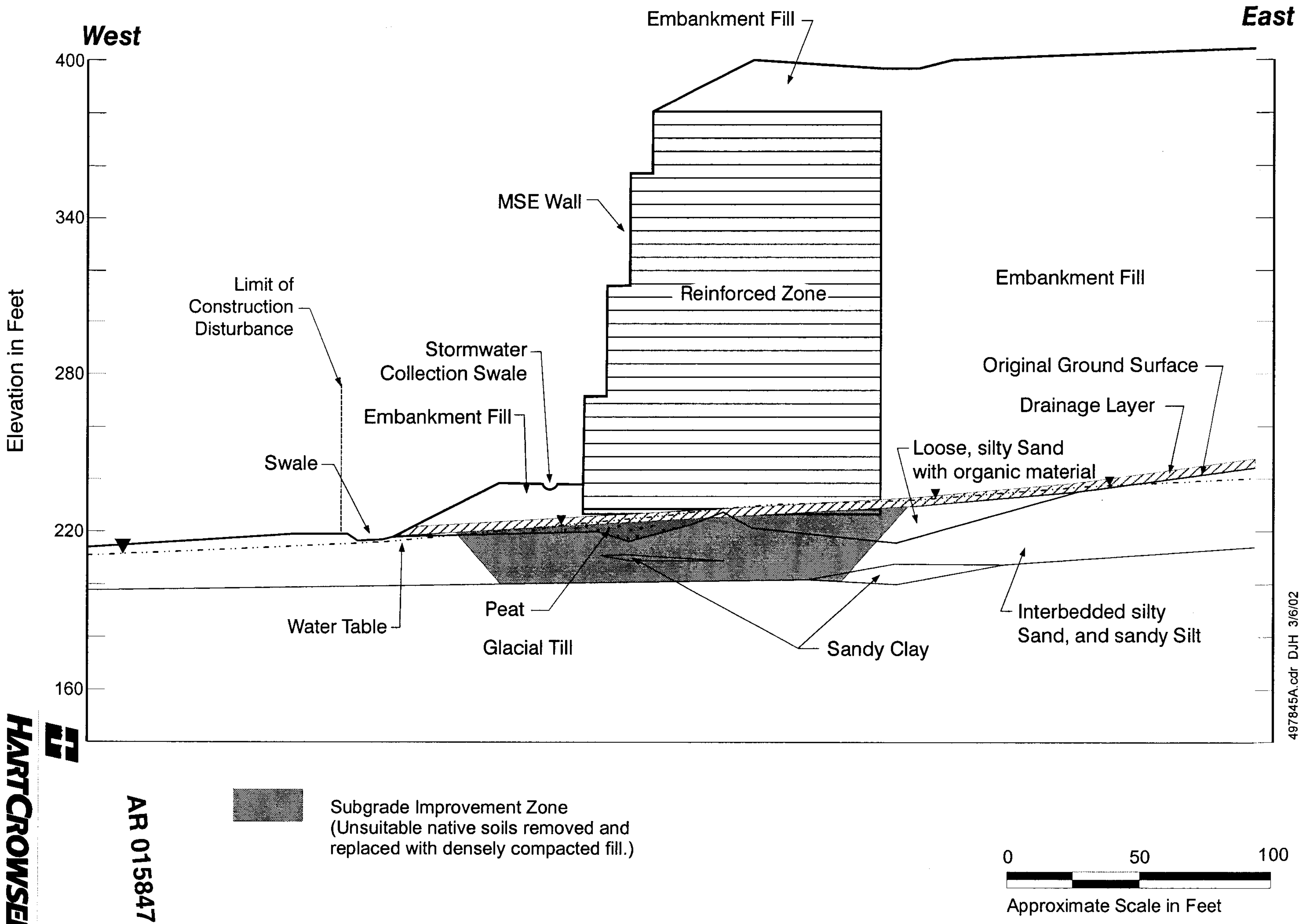

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Figure 1, Exhibit E