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U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

## 2.5.5 STABILITY OF SLOPES

REVIEW RESPONSIBILITIES

Primary - Hydrologic and Geotechnical Engineering Branch (HGEB)

Secondary - None

## I. AREAS OF REVIEW

Information, including analyses and substantiation, must be presented in the applicant's safety analysis report (SAR) and reviewed by the staff concerning the stability of all earth and rock slopes both natural and man-made (cuts, fills, embankments, dams, etc.) whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The following subjects must be evaluated using the applicant's data in the SAR and information available from other sources: slope characteristics (subsection 2.5.5.1); design criteria and design analyses (subsection 2.5.5.2); results of the investigations including borings, shafts, pits, trenches, and laboratory tests (subsection 2.5.5.3); properties of borrow material, compaction and excavation specifications (subsection 2.5.5.4).

The HGEB will coordinate other branch evaluations that interface with the Geotechnical Engineering aspects of the site as follows: Geosciences Branch (GB) will determine the adequacy of the geologic and seismic information cited in support of the applicant's conclusions concerning the suitability of the plant site and the stability of earth and rock slopes as part of its primary review responsibility for SRP Section 2.5.1. GB also reviews the seismological and geological investigations carried out to establish the ground motion environment for seismic design of the plant, the procedures and analysis used by the applicant in establishing the SSE and OBE for the site, and the seismic design bases for foundations as part of its primary review responsibility for SRP Section 2.5.2. The results of the stability evaluations of earth and rock slopes are reviewed by Structural Engineering Branch (SEB) to assure that displacements or failure of site slopes as indicated in the SAR do not have an adverse impact on structural components as part of its primary review responsibilities for SRP Sections 3.7 and 3.8.

Licensing Guidance Branch (LGB) will coordinate the review of technical specifications to insure that Geotechnical Engineering design features related to materials of construction and geometric arrangement of subsurface materials, foundations, cut slopes, and embankments, which if altered or modified would have a significant effect on safety, are included in conjunction with its primary review responsibility for SRP Section 16.0. Quality Assurance Branch (QAB) will coordinate the review of the Geotechnical Engineering aspects of the QA program pertaining to safety-related structures, systems, and components in conjunction with its primary review responsibility for SRP Section 17.1.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

## II. ACCEPTANCE CRITERIA

The applicable rules and basic acceptance criteria pertinent to the areas of this section of the Standard Review Plan are:

1. 10 CFR Part 50, §50.55a, "Codes and Standards." This rule requires that structures, systems, and components shall be designed, fabricated, erected, constructed, tested, and inspected in accordance with the requirement of applicable codes and standards commensurate with the importance of the safety function to be performed. (Ref. 1)

2. 10 CFR Part 50, Appendix A:

   (a) General Design Criterion 1 - "Quality Standards and Records." This criterion requires that structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. It also requires that appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit. (Ref. 2)

   (b) General Design Criterion 2 - "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related portions of the system shall be designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. (Ref. 3)

   (c) General Design Criterion 44 - "Cooling Water." This criterion requires that a system shall be provided with the safety function of transferring the combined heat load from structures, systems, and components important to safety to an ultimate heat sink under normal operating and accidental conditions. (Ref. 4)

3. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." This appendix establishes quality assurance requirements for the design, construction, and operation of those

structures, systems, and components of nuclear power plants that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. (Ref. 5)

4. 10 CFR Part 100, "Reactor Site Criteria." This part describes criteria which guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors. (Ref. 6)

5. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." These criteria describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and identifies geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants. (Ref. 7)

The following regulatory guides provide information, recommendations, and guidance and in general describe a basis acceptable to the staff that may be used to implement the requirements of 10 CFR Part 50, §50.55a; 10 CFR Part 50, Appendix A, General Design Criteria 1, 2, and 44; 10 CFR Part 50, Appendix B; 10 CFR Part 100; and 10 CFR Part 100, Appendix A.

1. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants." This guide describes a basis acceptable to the staff that may be used to implement General Design Criteria 2 and 44 with regard to the ultimate heat sink, including necessary retaining structures and the canals and conduits connecting the ultimate heat sink with the cooling water system intake structures. (Ref. 8)

2. Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)." This guide describes a method acceptable to the staff for complying with the Commission's regulations with regard to 10 CFR Part 50, Appendix B, overall quality assurance program requirements during design and construction of nuclear power plants. (Ref. 9)

3. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of site investigations related to geotechnical engineering aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundation and earthworks under anticipated loading conditions including earthquake in complying with 10 CFR Part 100 and 10 CFR Part 100, Appendix A. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, the spacing and depth of borings, and sampling. (Ref. 10)

4. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants." This guide describes laboratory investigations and testing practices acceptable for determining soil and rock properties and characteristics needed for engineering analysis and design for foundations and earthwork for nuclear power plants in complying with 10 CFR Part 100 and 10 CFR Part 100, Appendix A. (Ref. 11)

The information in the SAR must be in compliance with the criteria presented in References 1 through 7. This section of the SAR is judged acceptable if the information presented is sufficient to demonstrate the dynamic and static

stability of all slopes whose failure could adversely affect, directly or indirectly, safety-related structures of the nuclear plant or pose a hazard to the public. The emergency cooling water source is of particular interest with regard to slope stability (Refs. 4 and 8). The secondary source of emergency cooling water should survive the operating basis earthquake (OBE) and design basis flood. Completeness is determined by the ability to make an independent evaluation on the basis of information provided by the applicant.

Specific criteria necessary to meet the relevant requirements of the Commission regulations identified above are as follows:

Subsection 2.5.5.1. In meeting the requirements of References 3, 4, and 6 and the regulatory positions contained in References 8, 10, and 11, the discussion of slope characteristics is acceptable if the subsection includes:

1. Cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions.

2. A summary and description of static and dynamic properties of the soil and rock comprising seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Category I facilities. The text should include a complete discussion of procedures used to estimate, from the available field and laboratory data, conservative soil properties and profiles to be used in the analysis.

3. A summary and description of groundwater, seepage, and high and low groundwater conditions.

Subsection 2.5.5.2. In meeting the requirements of References 1, 2, 3, 6, and 7 and the regulatory positions of Reference 8, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all seismic Category I slopes are described and valid static and dynamic analyses have been presented to demonstrate that there is an adequate margin of safety. A number of different methods of analysis are available in the literature. Computer analyses should be verified by manual methods. Analysis using both deterministic and probabilistic approaches is desirable.

To be acceptable, the static analyses should include calculations with different assumptions and methods of analysis to assess the following factors:

1. The uncertainties with regard to the shape of the slope, boundaries of the several types of soil within the slope and their properties, the forces acting on the slope, and pore pressures acting within the slope.

2. Failure surfaces corresponding to the lowest factor of safety.

3. The effect of the assumptions inherent in the method of analysis used.

4. Adverse conditions such as high water levels due to the probable maximum flood (PMF), sudden drawdown, or steady seepage at various levels. In general, safety factors related to the slope hazard are needed; however, actual values depend somewhat on the method of analysis, on the assumptions concerning the soil properties, on construction techniques, and on the range of material parameters.

To be acceptable, the dynamic analyses must account for the effect of cyclic motion of the earthquake on soil strength properties. Actual test data are needed for both the in situ soils as well as for any materials used in the construction of dams or embankments. As discussed above, the various parameters, such as geometry, soil strength, modeling method (location and number of elements (mesh) if a finite-element analysis is used), and hydrodynamic and pore pressure forces, should be varied to show that there is an adequate margin of safety (Refs. 34 and 35). Where liquefaction is possible, major dam foundation slopes and embankments should be analyzed by state-of-the-art finite-element or finite-difference methods of analysis. Where there are liquefiable soils, changes in pore pressure due to cyclic loading must be considered in the analysis to assess not only the potential for liquefaction but also the effect of pore pressure increase on the stress-strain characteristic of the soil and the post-earthquake stability of the slopes.

Subsection 2.5.5.3. In meeting the requirements of Reference 7 and the regulatory positions of References 10 and 11, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses. The test data, which must meet the criteria set forth in Sections 2.5.1 and 2.5.4, could be presented in those sections and referenced in this subsection. Because dams, dikes, and natural or cut slopes are often remote from the main plant area, results of additional exploration, tests, and analyses for these areas should be presented in this subsection.

Subsection 2.5.5.4. In meeting the requirements of Reference 5 and the regulatory positions of References 9, 10, and 11, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes. Planned construction procedures and control of earthworks should be described. To be acceptable, the information must be given as discussed in subsection 2.5.4.5. Some of this information could be presented in subsection 2.5.4.5. Because dams, dikes, and other earthworks are often remote from the main seismic Category I structures, it is necessary to complete this information in this subsection. Quality control techniques and requirements during and following construction must also be discussed and referenced to quality assurance sections of the SAR.

## III. REVIEW PROCEDURES

The review process is conducted in a similar manner and concurrent with that described in SRP Sections 2.5.1, 2.5.2, and 2.5.4. The services of consultants may be used to aid the staff in geotechnical engineering evaluations regarding foundation engineering and slope stability analyses, particularly in the evaluation of safety-related and seismic Category I earthworks, earth and rock-fill dams, dikes, and reservoirs. Typical references used by the staff are listed in subsection VI of this SRP section.

An acceptance review is conducted to determine if the provided information is complete as outlined in the Standard Format (Ref. 12) and to judge whether or not the information presented is sufficient to permit an independent in-depth review and analysis of the safety of the proposed facility. After acceptance of the SAR, the results of site investigations such as borings, maps, logs of trenches, permeability test records, results of seismic investigations, laboratory test results, profiles, plot plans, and stability analyses are studied and cross-checked in considerable detail to determine whether or not the assumptions and analyses used in the design are conservative. The degree of conservatism required depends upon the type of analysis used, the reliability

of parameters considered in the slope stability analysis, the number of borings, the sampling program, the extent of the laboratory test program, and the resultant safety factor. In general, the applicable soil strength data should be conservatively selected for the various possible soil profiles and slope conditions. For lower safety factors, several soil profiles should be analyzed to insure that reasonable ranges of soil properties have been considered. Other factors such as flood conditions, pore pressure effects, possible erosion of soils, and possible seismic amplification effects should be conservatively assessed.

The design criteria and analyses are reviewed to ascertain that the techniques employed are appropriate and represent the present state-of-the-art. Staff comments and questions at this phase of the review, concerning the information in the SAR, are sent to the applicant as first-round questions (Q-1). An independent analysis of the design of safety-related earth or rock-fill embankments may be performed by the staff's advisors or by the staff as deemed necessary. Consultants may also evaluate natural or cut slopes, as required, on a case-by-case basis. The evaluations conducted by the staff and its advisors may identify additional unresolved items or reveal that the applicant's analyses are not conservative. Additional information is then requested in a second round of questions (Q-2), or a staff position is taken requiring conformance to a more conservative approach.

After completing the review, if the staff's conclusions are consistent with those reached by the applicant, these conclusions are summarized in the safety evaluation report (SER) or in a supplement to the SER. In the event that the applicant's investigation and design are not judged to be sufficiently conservative, a staff position is stated and the applicant is asked to further substantiate his position by additional investigations or monitoring to demonstrate that a failure of the slopes in question will not harm the safety functions of the plant, or to concur in the staff position.

The data needed to satisfy the requirements of this section are often incomplete in the early stages. However, sufficient field and laboratory data should be presented and conservatively interpreted to allow a realistic assessment of the safety of proposed slopes and supporting foundations. Detailed design investigations are usually still in progress and final design conclusions have often not been made. Because of this, the question and answer exchange is not generally complete at the Q-2 stage. Most of the open items of Section 2.5 remaining at the time that the safety evaluation report (SER) input is required are in the foundation engineering and slope stability areas because actual conditions may not be revealed until excavations are opened; site visits conducted after construction permit (CP) issuance are therefore necessary.

All natural safety-related slopes are examined during at least one of the two site visits required of the staff. Because excavated slopes or embankments are not usually constructed until after a construction permit has been granted, detailed as-built documentation of these slopes and embankments, as well as complete stability and safety analyses, are necessary in the FSAR.

Following is a brief description of the review procedures conducted by the staff in evaluating the slope stability aspects of nuclear power plant sites.

Subsection 2.5.5.1. Plot plans, cross sections, and profiles of all safety-related slopes in relation to the topography and physical properties of the underlying materials are reviewed and compared with exploratory records to

ascertain that the most critical conditions have been addressed and that the characteristics of all slopes have been defined. The soil and rock test data are reviewed to insure that there is sufficient relevant test data to verify the soil strength characteristics assumed for the slopes, dikes, and dams under analysis. The evaluation is to some extent a matter of engineering judgment; however, if the safety factors resulting from the analysis are not appropriate to the hazards posed by a slope failure and other than clearly conservative soil properties and profiles were used, the applicant is required to obtain additional data to verify his assumptions, or to show that, even if the worst possible conditions are assumed, there is an adequate margin of safety. With respect to seismic analysis, this subsection and subsection 2.5.5.2 are reviewed concurrently because different methods of analysis may involve different approximations, assumptions, and soil properties.

In addition to generic state-of-the-art literature, other potential sources of information are those containing design, construction, and performance records of natural slopes, excavation slopes, and dams that may have been constructed in the general vicinity of the nuclear power plant. Examples of such documents are design memoranda and construction reports regarding nearby projects of public agencies such as the Corps of Engineers, the Tennessee Valley Authority, the Bureau of Reclamation, and private construction contractors or architect-engineers.

Subsection 2.5.5.2. The criteria, design techniques, and analyses are evaluated by the staff to ascertain that:

1. Appropriate state-of-the-art methods have been employed.

2. Conservative assumptions regarding soil and rock properties have been used in the design and analysis of slopes and embankments as discussed above in subsection 2.5.5.1.

3. Appropriately conservative margins of safety have been incorporated in the design.

The criteria and design methods used by the applicant are reviewed to ascertain that state-of-the-art techniques are being employed. The design analyses are reviewed to be sure that the most conservative failure approach has been used and that all adverse conditions to which the slope might be subjected have been considered. Such conditions include ground motions from the safe shutdown earthquake, settlement, cracking, flood or low-water steadystate seepage, sudden drawdown of an adjacent reservoir, or a reasonable assumption of the possible simultaneous occurrence of two natural events such as an earthquake and flood. The review is also concerned with determining whether or not the soil and rock characteristics derived from the investigations described in subsection 2.5.5.3 have been completely and conservatively incorporated into the design. When marginal factors of safety are indicated by the independent analyses performed by the staff and its consultants, additional substantiation and refinement is required or the applicant must use more conservative assumptions.

No single method of analysis is entirely acceptable for all stability assessments; thus, no single method of analysis can be recommended. Relevant manuals issued by public agencies (such as the U.S. Navy Department, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation) are often used in reviews to ascertain whether the analyses performed by the applicant are reasonable

(Refs. 22, 26, 32, and 33). Many of the important interaction effects cannot be included in current analyses and must be treated in some approximate fashion. Engineering judgment is an important factor in the staff's review of the analyses and in assessing the adequacy of the resulting safety factors.

If the staff review indicates that questionable assumptions have been made by the applicant or some nonstandard or inappropriate method of analysis has been used, then the staff or its consultant may model the dam or slope in a manner which it feels is more consistent with the data and perform an independent analysis employing both deterministic and probabilistic methods as appropriate.

During the operating license review, all open items requiring resolution, including construction data and as-built analyses, settlement records, piezometer records, and absence of seepage, that support the adequacy and safety of the design, are reviewed by the staff.

Subsection 2.5.5.3. A comprehensive program of site investigations including borings, sampling, geophysical surveys, test pits, trenches, and laboratory and field testing must be carried out by the applicant to define the physical characteristics of all soil and rock beneath safety-related and seismic Category I slopes, and borrow material that is to be used to construct safety-related dams, fills, and embankments (Refs. 10 and 11). The staff reviews these investigations to ascertain that the program has been adequate to define the in situ and earthwork soil and rock characteristics. The decision as to the adequacy of the investigation program is based on the methods discussed in SRP Section 2.5.4.

Subsection 2.5.5.4. The preliminary specifications and quality control techniques to be used during construction are reviewed by the staff to ascertain that all design conditions are likely to be met (Refs. 5 and 9). During this part of the review the following are among those subjects reviewed for adequacy:

1. Proposed construction dewatering plan to ensure that it will not result in damage either to the natural or engineered foundation materials or to the structural foundation.

2. The excavation plan to remove all unsuitable materials from beneath the foundations and the quality control procedures which establish suitable materials.

3. The techniques and equipment to be used in compacting foundation and embankment materials.

4. The quality control and testing program to provide a high level of assurance that:

    a. The selected borrow material is as good and as relatively homogeneous as anticipated from the investigation program.

    b. The compacted foundation soil meets design specifications.

5. The techniques for improving the stability of natural slopes such as drainage, grouting, rock bolting, and applying gunite.

6. The plans for monitoring during and after construction to detect occurrences that could detrimentally affect the facility. Such monitoring includes

periodic examination of slopes, survey of settlement monuments, and measurements of local wells and piezometers.

## IV. EVALUATION FINDINGS

Upon completion of the staff's review of the geotechnical engineering aspects of the material presented by the applicant related to the stability of all earth and rock slopes, both natural and man-made, an evaluation of completeness, accuracy and adequacy is made. If the evaluation confirms that the applicant has met the requirements and regulatory positions of References 1 through 11, the conclusion in the SER states that the investigations performed for slope stability studies and dam and dike analyses are adequate to justify the soil and rock characteristics used in the design, and that the design analyses contain margins of safety which adequately demonstrate that natural and man-made slopes will remain stable under SSE conditions and that safety-related earthwork will function reliably.

The staff's conclusions regarding the stability of slopes are summarized in the safety evaluation report (SER) or in a supplement to the SER. The following is an example:

> Both natural and man-made slopes exist at the site. At the plant site, which is located several hundred feet from the Green Valley and about 280 feet above the level of Jones Pond, the slope is relatively gentle for about 250 feet west of the westernmost Category I structures, then steepens, attaining an angle of more than 45° near the bottom of the valley wall. Major structural trends, schistosity, and one of the predominant joint trends are nearly perpendicular to the slope. A second predominant joint set is nearly parallel to the river and dips to the southwest, but no slope movements have apparently affected the valley walls in the vicinity of the site. Seven other joint trends were detected by the applicant. These joint sets are reported to be moderately spaced and discontinuous. The applicant has drilled several exploratory holes and cored others to assess the natural slope characteristics and groundwater regime. Even though the natural slopes are some distance from safety-related plant facilities and slope failures are not obvious safety hazards, the applicant has performed stability analyses of these slopes under safe shutdown earthquake (SSE) conditions. The minimum computed safety factor was 1.6 using conservative slope and material parameters.
>
> Man-made earth slopes related to the safety of the plant include excavation cuts for the ultimate heat sink canal and dams and dikes for the ultimate heat sink storage pond. An extensive investigation and test program has determined all the significant characteristics and properties of cut slopes and fill embankments. Earthwork compaction criteria, construction control, and select fill materials are consistent with high-quality water-retention facilities. Conservative stability analyses of these slopes under SSE conditions indicated minimum safety factors of 1.5.
>
> The staff concludes that information including analysis and substantiation presented by the applicant is sufficient to demonstrate the dynamic and static stability of all slopes whose failure could adversely affect directly or indirectly safety-related structures of

the nuclear plant or pose a hazard to the public and meets the requirements of the pertinent Commission's regulations (site appropriate References 1 through 7).

The applicant has met the requirements of the pertinent Commission's regulations (cite appropriate References 1 through 7) with respect to slope characteristics; design criteria and design analyses; results of investigations including borings, shafts, pits, trenches, and laboratory tests; properties of borrow materials; and compaction and excavation specifications by meeting the regulatory position in Regulatory Guide (cite appropriate References 8 through 11) or by providing and meeting an alternative method to these regulatory positions that the staff has reviewed and found to be acceptable.

Based on the results of the applicant's investigations, laboratory and field tests, analyses, and criteria for design and construction, we and our consultants conclude that natural and man-made slopes will remain stable under SSE conditions and that safety-related earthworks will function reliably.

## V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

## VI. REFERENCES


1. 10 CFR Part 50, §50.55a, "Codes and Standards."

2. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

3. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

4. 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."

5. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

6. 10 CFR Part 100, "Reactor Site Criteria."

7. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

8. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."

9. Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)."

10. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."

11. Regulatory Guide 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants."

12. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

13. Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers.

14. Book of ASTM Standards and Special Technical Publications, American Society for Testing and Materials.

15. Geotechnique, The Institution of Civil Engineers, London.

16. Earthquake Engineering Research Center, University of California, Berkeley.

17. M. Juul Hvorslev, "Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes," Waterways Experiment Station, U.S. Army Corps of Engineers, November 1949.

18. GEODEX INTERNATIONAL, Soil Mechanics Information Service, Sonoma, California.

19. Engineering Manual EM 1110-2-1907, "Soil Sampling," U.S. Army Corps of Engineers, March 1972.

20. Engineering Manual EM 1110-2-1908, "Instrumentation of Earth and Rock Fill Dams," U.S. Army Corps of Engineers, August 1971.

21. Engineering Manual EM 1110-2-1906, "Laboratory Soil Testing," U.S. Army Corps of Engineers, November 1970.

22. Corps of Engineers, "Engineering and Design Stability of Earth and Rock-Fill Dams," Manual N. EM 1110-2-1902, Office fo the Chief of Engineers, Dept. of the Army (1970).

23. "ASCE Soil Mechanics and Foundation Division Conference on Stability and Performance of Slopes and Embankments, August 22-26, 1966," published in J. Soil Mech. and Found., ASCE, Vol. 93 (1967).

24. P. Chakrabarti and A. K. Chopra, "A Computer Program for Earthquake Analysis of Gravity Dams Including Hydrodynamic Interaction," Report No. EERC-73-7, Earthquake Engineering Research Center, Univ. of California, Berkeley (1973).

25. I. M. Idriss, J. Lysmer, R. Hwang, and H. B. Seed, "Quad-4: A Computer Program for Evaluating the Seismic Responses of Soil Structures by Variable Damping Finite Element Procedures," Report No. EERC 73-16, Earthquake Engineering Research Center, Univ. of California, Berkeley (1973).

26. Bureau of Reclamation, "Earth Manual," First Edition, U.S. Dept. of Interior (1968).

27. K. Stagg and O. Zienkiewicz, "Rock Mechanics in Engineering Practice," John Wiley & Sons (1968).

28. Shannon & Wilson, Inc. and Agbabian-Jacobsen Associates, "Soil Behavior Under Earthquake Loading Conditions - State-of-the-Art Evaluation of Characteristics for Seismic Responses Analyses," U.S. Atomic Energy Commission Contract W-7405-eng-26, January 1972.

29. F. H. Kulhawy, J. M. Duncan, and H. B. Seed, "Finite Element Analysis of Stresses and Movements in Embankments During Construction," Report No. TE-69-4, U.S. Army Engineers Waterways Experiment Station, Vicksburg (1969).

30. K. Terzaghi and R. B. Peck, "Soil Mechanics in Engineering Practice," 2nd ed., John Wiley & Sons (1967).

31. J. W. Snyder, "Pore Pressures in Embankment Foundations," Report S-28-2, U.S. Army Engineers Waterways Experiment Station, Vicksburg (1968).

32. Corps of Engineers, "Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)," Tech. Report TM 5-818-1 (formerly EM 1110-345-147), Office of the Chief of Engineers, Dept. of the Army (1965).

33. Department of the Navy, "Soil Mechanics, Foundations, and Earth Structures," NAVFAC DM-7, March 1971.

34. H. Bolton Seed, K. L. Lee, I. M. Idriss, and F. Makdisi, "Analysis of the Slides in the San Fernando Dams During the Earthquake of February 9, 1971," Report No. EERC 73-2, Earthquake Engineering Research Center, University of California, Berkeley (1973).

35. N. M. Newmark, "Effects of Earthquakes on Dams and Embankments," Geotechnique, 15: 140-141; 156, 1969.