U.S. NUCLEAR REGULATORY COMMISSION

July 2010
Revision 1

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.13

(Draft was issued as DG-3040, dated February 2010)

DESIGN, CONSTRUCTION, AND INSPECTION OF EMBANKMENT RETENTION SYSTEMS AT FUEL CYCLE FACILITIES

A. INTRODUCTION

This guide describes some engineering practices and methods generally considered by the U.S. Nuclear Regulatory Commission (NRC) to be satisfactory for the design, construction, and inspection of embankment retention systems used for retaining solid and liquid effluent from nuclear fuel cycle facility operations other than uranium recovery and milling operations. These practices and methods are the result of NRC review and action on a number of specific cases, and they reflect the latest general engineering approaches that are acceptable to the NRC staff. If future information results in alternative methods, the NRC staff will review such methods to determine their acceptability.

Title 10, Section 20.1101, "Radiation Protection Programs," of the *Code of Federal Regulations* (10 CFR 20.1101) (Ref. 1) requires licensees who possess, process, refine, or use uranium ores and oxides in fuel cycle facilities to use, to the extent practical, procedures and engineering controls based on sound radiation protection principles to maintain occupational radiation exposure and radiation exposure to members of the public that are as low as is reasonably achievable (ALARA). In addition, Subpart B, "Environmental Standards for the Uranium Fuel Cycle," of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations" (Ref. 2) requires that the annual dose equivalent not exceed 25×10^{-5} sieverts (Sv) (25 millirem (mrem)) to the whole body, 75×10^{-5} Sv (75 mrem) to the thyroid, and 25×10^{-5} Sv (25 mrem) to any other organ of any member of the public as the result of exposures to radiation (radon and its daughters excepted) from nuclear fuel cycle operations, including planned discharges of radioactive materials to the general environment. Liquid and solid wastes generated at fuel cycle facilities typically contain radioactive materials in excess of the discharge limits and are generally confined by an embankment retention system to allow the solids to precipitate. The liquid is sampled for radiological or hazardous contents prior to release to the environment.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 20, Part 40, and Part 70 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0014, 3150-0020, and 3150-0009 respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Background

The manufacture of nuclear fuel results in the production of liquid and solid wastes. Fuel cycle facilities have used embankment retention systems for both temporary and long-term storage of solid and liquid discharge. Effluent from the various processes dictates the requirement for release or retention. Factors pertaining to safety, contamination, and environmental damage determine the minimum requirements in planning and constructing retention systems.

Uranium hexafluoride (UF_6) production and fuel fabrication effluent does not contain constituents of long-lived radionuclides (e.g., radium-226) associated with uranium recovery processes. Environmental processing facilities associated with the fuel production and fabrication are able to treat liquid effluent and release it to the environment in compliance with the requirements of Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to 10 CFR Part 20, "Standards for Protection against Radiation" (Ref. 3). The variation in construction to allow for release to the environment or to retain and not release is the prerogative of the applicant. The NRC staff reviews such variations on a case-by-case basis, or a State reviews them in accordance with the terms contained in the applicant's Ground Water Discharge Permit.

1. General Planning, Siting, and Design Considerations

The following general design considerations are based on the requirements of Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material," (Ref. 4).

Because the prime functions of the retention system are to store radioactive solids and/or to provide temporary storage of contaminated water, the system must be designed and constructed to remain stable for its intended life. The retention system must be designed to provide sufficient storage capacity at any given time during its intended life, and it must provide sufficient control of seepage to prevent unacceptable contamination of adjacent land, waterways, and ground waters. The retention system must also be designed to be resistant to wind and water erosion during and after facility operations. The design and construction considerations, along with the sound evaluation and inspection principles in this guide, should be used in embankment retention systems associated with fuel production facilities.

The planning, siting, and design of each retention system must comply with any other regulatory and permitting requirements for a proposed impoundment that exist outside of the NRC's regulations in Appendix A to 10 CFR Part 40.

1.1 Site Evaluation

In selecting any site for fuel cycle facility effluent retention, local conditions, including climate, ground water and surface water hydrology, geology, and seismology, should be assessed and their impacts evaluated. In site selection, features that should be considered include (1) hydrologic and other natural conditions as they contribute to continued immobilization and isolation of contaminants from ground water sources, (2) potential for minimizing erosion, disturbance, and dispersion by natural forces over the long term, and (3) security in the form of a fence to restrict access by animals and unauthorized individuals.

1.2 Field Exploration

Subsurface investigations at the site of the retention system should be of adequate scope to determine the suitability of the foundation and characteristics of embankment materials. Borings should be drilled along the axis of the retention structure and at critical locations perpendicular to the axis to establish geologic sections and ground water conditions. Borings should extend to a depth in the natural soils at least equal to the height of the planned embankment section. The investigations should cover classification, physical and chemical properties, location, and extent of soil and rock strata, and variations in ground water conditions. Evaluation of ground water should be focused on the uppermost aquifer. The field exploration should identify this aquifer, its flow direction, and the distance from the impoundment to potential downgradient users. In addition, the preoperational background quality of ground water in the uppermost aquifer should be ascertained. Observation of ground water conditions should be recorded over a sufficient period to permit the ground water depths and range of seasonal fluctuations to be established.

The foundation conditions should be evaluated to assess the ability of subsurface materials to support the embankments without failure and without excessive total or differential settlement. The permeability of foundation soils and rocks should be ascertained to estimate the seepage potential. Information is needed on the characteristics of the underlying soil as they will control transport of contaminants and solutions.

1.3 Laboratory Tests

Testing soil samples of foundation and embankment materials from the field investigation should provide detailed information on the physical and mechanical properties such as classification, gradation, shear strength, consolidation, permeability, sedimentation, compaction, piping and cracking susceptibility, and wind-water erosion characteristics.

2. Design Analysis

Design analysis should consider stability, settlement, seepage, hydrologic analyses, liner stability, and liner compatibility. Specifically, the design should ensure that retention system failure will not occur. Historical records indicate that most failures associated with retention systems have been caused by overtopping by floodwaters, erosion, piping in the retention embankment or the foundation, foundation failure, slope failure, or liquefaction.

2.1 Stability and Failure Analyses

2.1.1 Slope Stability

Stability analyses involve comparing the shearing stresses along potential failure surfaces with the available shearing resistance along those surfaces. The factor of safety is the ratio of the available shear strength to the developed maximum shear stress. A number of computer programs can be used to perform slope stability analyses. Commercially available programs also may allow calculation of the factor of safety. The output from a computer program should be checked carefully to verify that the critical surface with the lowest factor of safety has been identified, the critical surface represents a possible or realistic scenario, and computational problems resulting from the parameters used are minimized. In EM 1110-2-1902, “Engineering and Design Slope Stability,” issued October 2003, the U.S. Army Corps of Engineers describes pertinent basic design considerations, methods of stability analysis, and minimum factors of safety that provide an acceptable design basis for a safe settling or retention basin structure, (Ref. 5).

2.1.2 Liquefaction

The impact of liquefaction on stability should be considered, if potentially liquefiable soils exist below the site of a retention system. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. The U.S. Environmental Protection Agency report EPA/600/R-95/051, “RCRA Subtitle D (258): Seismic Design Guidance for Municipal Solid Waste Landfill Facilities,” issued April 1995, elaborates on five criteria for determining whether a site has potentially liquefiable soils—(1) geologic age and origin, (2) fines content and plasticity index, (3) saturation, (4) depth below ground surface, and (5) soil penetration resistance (Ref. 6). If liquefaction potential exists at a retention system site, additional subsurface investigation may be necessary.

2.1.3 Settlement

If the foundation beneath an embankment retention system consists of layers of compressible soils or weathered rock, or if the bedrock profile is very irregular, differential settlements could result from uneven loading or variable thicknesses in the compressible soils. Total settlement and differential settlements may cause cracking and/or excessive strain in the embankments or other retention system components that could lead to system failure.

After settlement analyses have been performed, the engineered components of the waste retention system, such as geotextiles, geomembranes, clay liners, drainage layers, effluent collection piping, and waste piping, should be analyzed for tensile strain. The analysis should verify that the components can maintain their integrity when subjected to the induced strain associated with the settlement determined in the total and differential settlement analyses. If analysis indicates that settlement along any cross-section is likely to damage an engineered component, or to cause the engineered component to be unable to meet the minimum design criteria, then the retention system must be redesigned to eliminate the adverse effects of total and differential settlement. Methods such as overbuilding, surcharging, removal of the material causing the problem, or engineered reinforcement may be used to mitigate the effects of settlement.

2.2 Water Control and Management

2.2.1 Impoundment Storage Capacity

Some catchment areas contribute runoff into the retention system. This generally will be the area of the system itself, and the runoff will result from precipitation. This does not present a problem, as it only further dilutes any potential activity in the embankment retention system. Grading and diversion channels should be provided to enhance natural drainage if necessary.

When the probability of occurrence of large floods on small drainage basins in arid regions is small and onsite personnel are available to repair any minor damage that could occur, the NRC staff may accept less conservative options for determining the design-basis flood. For small retention systems built in isolated areas where failure would neither jeopardize human life nor create damage to property or the environment beyond the licensee's legal liabilities and financial capabilities, the design need not use extremely conservative flood design criteria. However, the selection of the design flood should be at least compatible with the hazard category guidelines set forth by the U.S. Army Corps of Engineers (Ref. 7).

2.2.2 Seepage Control

When retention systems are lined, seepage analysis for embankment stability purposes is unnecessary. However, special design features, such as impervious liners and collection systems, are needed to maintain the quality and quantity of seepage from the retention system within tolerable limits of water supply and pollution control requirements. If a clay liner is proposed, seepage into this layer must be assessed to ensure that seepage will not occur through the liner (Criterion 5 of Appendix A to 10 CFR Part 40).

The potential for seepage at an embankment retention system can be controlled through installation of a liner system. The interior of each retention or settling basin should be lined with an essentially impervious synthetic lining material designed to prevent seepage. The number of construction joints and penetrations of the liner should be minimized, and protection from mechanical damage should be provided. The liner can be constructed of earthen material, such as compacted clay, or synthetic material, such as a high-density polyethylene geomembrane. The design of a liner system should consider subgrade material, type of liner system (earthen or synthetic), liner system protection, and leak detection. Both types of liner systems have advantages and disadvantages, and the choice of the liner system should consider several factors. A key factor is the liner material's physical and chemical inertness when exposed to the materials within the retention system. The chemical qualities of the effluent must be assessed to determine the impacts on liners and/or the environment (Criterion 5 of Appendix A to 10 CFR Part 40).

The advantages of a synthetic liner system include a significantly reduced thickness, a greater resistance to cracking, and a much lower hydraulic conductivity (typically several orders of magnitude lower than that of an earthen liner system). The design of a synthetic liner system should consider the method of placement, the seaming techniques, and the puncture resistance. Theory and design methods to evaluate puncture resistance have been developed and can be used to evaluate the puncture resistance of synthetics for different conditions (Refs. 8-10).

3. Construction Considerations

The construction of embankment retention systems generally involves both excavation and filling in some specified order. Successful embankment retention system construction requires understanding the moisture/density relationships of the soils, providing adequate compaction, and preventing poor-quality soils from being incorporated into the embankment retention system fill materials. Clearing and stripping operations provide much additional information on the characteristics of foundations, and this information may confirm or contradict design assumptions based on earlier geotechnical investigations. Weather and ground water conditions during construction may significantly alter water contents of proposed fill material or create seepage and/or hydraulic conditions necessitating modifications in design. Projects should be evaluated and "reengineered" continuously during construction to ensure that the final design is compatible with conditions encountered during construction. Construction supervision, management, and monitoring of the embankment and associated structures are a critical part of the overall project management plan. Once the facility is placed into operation, observations, surveillance, inspections, and continuing evaluation are required to ensure the satisfactory performance of the retention system (Criterion 12 of Appendix A to 10 CFR Part 40).

4. Inspection and Maintenance

Conditions can change throughout the life of the embankment retention system. Such changes can significantly affect the factors governing the stability of a retention system. Therefore, a continuous program of inspection of the retention system is strongly recommended, beginning at the start of construction. Each site and structure has its own characteristics and its own susceptibilities to problems, and the inspection program should be tailored to consider these. Thorough physical examination is an essential part of the inspection program. The optimal frequency of inspections depends on the size and condition of the facilities, the character of the foundation, the regional geological setting, and the consequences of failure, such as jeopardizing human health and safety and inflicting property and environmental damage. Monitoring and analysis of performance data are necessary to ensure detection of adverse conditions (Criterion 12 of Appendix A to 10 CFR Part 40).

Before the operational use of the system begins, records of ground water levels (including seasonal fluctuations), ground water quality, ground elevations, and background radioactivities at the site should be compiled and compared with the operational conditions of the impoundment. Once operational activities begin, inspection should be performed at regular intervals to check the condition of the retention systems and associated facilities and to evaluate their structural safety and operational adequacy. A detailed, systematic inspection program should consist of, but not necessarily be limited to, the elements described in the sections below (10 CFR 40.27(b)(2)).

4.1 Engineering Data Compilation

Engineering data related to the design, construction, and operation of the retention systems should be compiled and, to the extent practicable, included in the initial inspection report. Most engineering data are readily available in documents filed for the license application. A detailed reference to the original documents kept at the project site should be adequate. These data should include the following items, as available and applicable:

- general project data, including regional vicinity maps showing the project location and the upstream and downstream drainage areas and as-built drawings and photographs of the retention system

- hydrologic and hydraulic data, including drainage area and basin characteristics, storage volume, surcharge capacity for floods, rate of inflow, elevation of the maximum design pool, and freeboard height

- foundation data and geological features, including boring logs, geological maps, profiles, and cross-sections

- properties of embankment and foundation materials, including results of laboratory and field tests, and assumed design material properties

- principal design assumptions and analyses, including hydrologic and hydraulic analyses, stability and stress analyses, and seepage and settlement analyses

- pertinent construction photographs and records, including construction control tests, construction problems and modifications, and maintenance repairs

4.2 Inspection Programs

The embankment retention system inspection program should be established and conducted systematically to minimize the possibility of overlooking any significant features. A checklist should be developed and followed to document the observations of each significant feature. Photographs for comparison of previous and present conditions may be used as a part of the inspection program. The inspection program should include, but not be limited to, the following as appropriate:

- Semiannual Inspection

  - Pond water elevations should be examined and recorded to ensure that minimum freeboard is maintained.

  - The transport system should be examined for any evidence of obstruction of the pipes or pumps caused by clogging or ice accumulation. The pipe couplings should be examined for leakage, and any flow rate sensor should be tested.

  - The liner system should be visually inspected to identify any damage to the liner and any operating practices that may contribute to liner damage.

  - Channels should be examined for channel bank erosion, bed aggradation or degradation and siltation, obstruction to flow, undesirable vegetation, or any unusual or inadequate operational behavior.

  - Any installed instrumentation, such as survey monuments, settlement plates or gauges, and/or piezometers, should be examined and tested for proper functioning. The available records and readings of these instruments should be reviewed to detect any unusual performance or distress of the structure.

  - The top of the embankment and downstream toe areas should be examined and surveyed, if necessary, for any evidence of unusual localized or overall settlement or depressions.

  - Embankment slopes should be examined for irregularities in alignment and variance from originally constructed slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, erosion, and surface cracks that indicate movement.

- The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches. The adequacy of slope protection against waves and surface runoff that may occur at the site should be evaluated.
- The maintenance of operating facilities and features (such as pumps and valves) that pertain to the safety of the retention system should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the retention system in a safe operating condition.
- The general long-term performance of the liner, such as its resistance to degradation, should be examined.

- Periodic Inspection (preferably bi-annual) should be performed by an independent geotechnical consultant to ascertain the condition of the embankment, which protects the retention basins.
- Special Inspections
  - Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events.
  - The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any uranium fuel cycle facility embankments that fall within the scope of the program.

4.3 Technical Evaluation

The existing conditions of the retention system should be evaluated annually unless changing conditions dictate a shorter period. This evaluation should include an assessment of the hydraulic and hydrologic capacities, water quality, and structural stability and should take into account both existing conditions and any changing conditions. In addition, surface water and ground water sampling data should be collected at the time of the technical evaluation to detect any patterns that could be a sign of failure of seepage control measures or foundation distress.

4.4 Inspection Reporting

A report should be prepared to present the results of each technical evaluation and the inspection data accumulated since the last report. These documents should be kept at the project site for reference purposes, available for inspection by regulatory authorities, and retired only upon termination of the project. Any abnormal hazardous conditions observed during the inspection should be reported immediately to the NRC staff.

4.5 Inspection Personnel

An experienced professional who is thoroughly familiar with the investigation, design, construction, and operation of these types of facilities should direct the planning and conduct of the inspections and evaluations. At each facility, this individual should ensure that all field inspectors are trained to recognize and assess signs of possible distress or abnormality.

C. REGULATORY POSITION

The following describes acceptable criteria for proposed construction, inspection, and performance of a fuel cycle facility waste retention system. If an applicant proposes the use of an alternative method or new information that may be developed in the future, the NRC will review the proposal and, if acceptable, approve its use.

1. Basic Design Criteria

a. The stability of the retention system is fundamental to design for construction and operation. In ensuring structural integrity, it should not be presumed that the liner system will function without leakage during the active life of the impoundment.

b. Consider total and differential settlement within tolerable limits that will not result in harmful cracking and embankment instability.

c. A liner's design, construction, and installation should limit any uncontrolled migration of effluent out of the impoundment to the adjacent subsurface soil, ground water, or surface water.

d. Recommended liner characteristics (Criterion 5 of Appendix A to 10 CFR Part 40):

   (1) The liner must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure from pressure gradients, physical contact with the effluent to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation.

   (2) The liner must be placed on a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner from settlement, compression, or uplift.

   (3) The liner must be installed in such a way that it will cover all surrounding earth likely to be in contact with effluent.

e. Consideration for installation of a leakage detection system to ensure that major liner failures are detected if they occur.

f. Allow sufficient freeboard to minimize overtopping by flood inflows and wind-generated waves and should include an allowance for settlement of the foundation and embankments.

g. Minimize upstream rainfall catchment areas to limit erosion potential and the size of the floods that could erode or wash out sections of the retention system.

2. Methods of Analysis

a. Wave runup may be determined using procedures discussed in the U.S. Army Corps of Engineers "Coastal Engineering Manual," issued April 2002 (Ref. 11).

b. The static stability of the embankment should be analyzed using commonly accepted detailed stability methods. The analysis should use appropriate static soil and rock properties established on tested representative samples over anticipated in situ and placement conditions.

c. Evaluation of liquefaction potential should include laboratory testing, in situ testing, and comparisons to similar soil deposits. Screening criteria should be used to determine whether there are potentially liquefiable soils at a site. The factor of safety for liquefaction potential should be greater than 1.0.

d. Appropriate laboratory test results should be used to estimate the rate and magnitude of settlement.

3. Construction Methods

a. Conventional acceptable engineering practices of construction control for water retention dams (e.g., controls on foundation preparation, suitability of materials, proper placement, field moisture, and density).

b. Installation of a synthetic liner system should focus on minimizing liner damage. Damage can occur in the form of wrinkles, improper seaming techniques, poor synthetic panel orientation, and punctures caused by construction equipment.

4. Inspection and Maintenance

a. A systematic inspection and maintenance program should be established to detect and repair damage that might lessen the integrity of the retention system. Generally, visual inspections performed on a regular basis and supplemented by adequate instrumentation are acceptable.

b. Semiannual inspections of retention systems should be planned, conducted, evaluated, and documented under the direction of an experienced professional who is familiar with the design, construction, and operation of these types of facilities. The licensee should retain documentation (i.e., a record) of each inspection for 3 years after the documentation is made.

c. Unscheduled inspections should be performed after the occurrence of significant earthquakes, tornadoes, floods, intense local rainfalls, or other unusual events. The NRC's implementation of the National Dam Safety Program and its associated guidelines may require special inspections of any fuel cycle facility embankments that fall within the scope of the program.

d. The inspection and maintenance program should start at the beginning of construction and continue at least through the operation of the facility.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

GLOSSARY

This guide uses the following definitions:

Embankment: A dike or ridge of either natural or man-made materials used to prevent the movement of liquids, sludges, solids or other materials.

Earthen Embankment Retention System: A watertight system of one or more settling and/or retention basins, including their associated engineered safety features.

Retention Basin: A watertight basin in which liquid, sludge, or solid wastes are held for one or more of the following reasons – (1) analysis to verify activity levels permitting release, (2) evaporation, and (3) recycle for treatment.

Settling Basin: A watertight basin designed for separating sludges and sediments as a layer on the bottom. The liquid is disposed of by overflow to the environment, transfer to a retention basin, or solar evaporation.

REFERENCES[1]

1. 10 CFR 20.1101, "Radiation Protection Programs," U. S. Nuclear Regulatory Commission, Washington, DC.

2. 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," U. S. Nuclear Regulatory Commission, Washington, DC.

3. Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to 10 CFR Part 20, "Standards for Protection against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC.

4. Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material," U.S. Nuclear Regulatory Commission, Washington, DC.

5. EM 1110-2-1902, "Engineering and Design Slope Stability," U.S. Army Corps of Engineers, Washington, DC, October 2003. [2]

6. EPA/600/R-95/051, "RCRA Subtitle D (258): Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," U.S. Environmental Protection Agency, Washington, DC, April 1995.[3]

7. ER 1110-2-106, "Recommended Guidelines for Safety Inspection of Dams," Table 3, U.S. Army Corps of Engineers, Washington, DC, September 1979.

8. R.F. Wilson-Fahmy, D.B. Narejo, and R.M. Koerner, "Puncture Protection of Geomembranes, Part I—Theory," *Geosynthetics International*, 3(5), 1996.[4]

9. D.B. Narejo, R.M. Koerner, and R.F. Wilson-Fahmy, "Puncture Protection of Geomembranes, Part II—Experimental," *Geosynthetics International*, 3(5), 1996.

10. R.M. Koerner, R.F. Wilson-Fahmy, and D.B. Narejo, "Puncture Protection of Geomembranes, Part III—Examples," *Geosynthetics International*, 3(5), 1996.

---

[1] Publicly available NRC published documents are available electronically through the Electronic Reading room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail PDR.Resource@nrc.gov.

[2] Electronic copies of public U.S. Army Corps of Engineers (USACE) publications are available for free download from the Internet at http://www.usace.army.mil/inet/usace-docs/. This site is the only repository for all official USACE engineer regulations, circulars, manuals, and other documents originating from HQUSACE. Publications are provided in portable document format (PDF).

[3] Electronic copies of publicly available U.S. Environmental Protection Agency (EPA) publications are available for free download from the Internet at http://www.epa.gov/nscep/. Hard copies are available for purchase from the EPA National Library Network at US EPA, Mail Code 3404T, 1200 Pennsylvania Avenue NW, Washington, DC 20460; telephone 202-566-0556.

[4] Copies of listed Geosynthetics International journal articles are available for purchase from the Institute of Civil Engineers, Thomas Telford Ltd., 40 March Wall, London, England, E14 9TP, telephone: +44 (0) 20 7665 2460 / 2418, or e-mail at Orders@icevl.com.

11. EM 1110-2-1100, “Coastal Engineering Manual,” U.S. Army Corps of Engineers, Washington, DC.

12. NUREG/BR-0216, “Radioactive Waste: Production, Storage, and Disposal,” Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, May 2002.

BIBLIOGRAPHY

1. Regulatory Guide 3.11, “Design, Construction, and Inspection of Embankment Retention Systems at Uranium Recovery Facilities,” US Nuclear Regulatory Commission, Washington, DC.

2 Regulatory Guide 1.127, “Inspection of Water-Control Structures Associated with Nuclear Power Plants,” US Nuclear Regulatory Commission, Washington, DC.

3. Regulatory Guide 1.132, “site Investigations for Foundations of Nuclear Power Plants,” US Nuclear Regulatory Commission, Washington, DC.

4. Regulatory Guide 1.138, “Laboratory Investigations of soils and rocks for Engineering analysis and Design of Nuclear Power Plants,” US Nuclear Regulatory Commission, Washington, DC.

5. Regulatory Guide 1.198, “Procedures and Criteria for Assessing Seismic soil Liquefaction at Nuclear Power Plants,” US Nuclear Regulatory Commission, Washington, DC.

6. Regulatory Guide 1.59, “Design Basis Floods at Nuclear Power Plants,” US Nuclear Regulatory Commission, Washington, DC.