NUREG-0902

Site Suitability, Selection and Characterization

Branch Technical Position -- Low-Level Waste Licensing Branch

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

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UNITED STATES NUCLEAR REGULATORY COMMISSION

LOW-LEVEL WASTE LICENSING BRANCH

TECHNICAL POSITION - SITE SUITABILITY, SELECTION, AND CHARACTERIZATION

Background

The Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 give the Nuclear Regulatory Commission (NRC) the responsibility for the licensing and regulation of commercial nuclear facilities from the standpoint of public health and safety. The NRC is also responsible to assure that these commercial nuclear facilities comply with the National Environmental Policy Act (NEPA) of 1969. The licensing requirements for near-surface disposal of low-level radioactive wastes are in the proposed rule, 10 CFR Part 61. The licensing requirements related to environmental protection are in 10 CFR Part 51.

With passage of the Low-Level Radioactive Waste Policy Act of 1980, Congress mandated that each state is responsible for the safe disposal of low-level radioactive wastes generated by non-defense sources within its boundaries and encouraged the states to form interstate compacts, subject to the approval of Congress, for the purpose of establishing and operating regional low-level radioactive waste disposal sites. The NRC is aware that initial steps have been taken which will lead to development of new sites for such disposal. In order to provide timely assistance in this process, the NRC is issuing this technical position paper on site suitability requirements, the site selection process, and site characterization activities for a near-surface disposal facility.

Introduction

The proposed rule, 10 CFR Part 61, defines a near-surface disposal facility as a land disposal facility in which radioactive waste is disposed of in or within the upper 15-20 meters (or greater) of the earth's surface. The proposed rule specifies licensing procedures, performance objectives, and minimum technical requirements in the subject areas of site suitability, site design, facility operations, site closure, environmental monitoring, waste classification, waste

characteristics, waste labeling, land ownership, and institutional controls for near-surface disposal facilities. The performance objectives in Subpart C of the proposed 10 CFR Part 61 relate to the performance of the near-surface disposal facility as a total system. The minimum technical requirements have been placed on individual components within the system to assure that the total system will meet the performance objectives.

This technical position paper addresses three subject areas that are integral to the licensing of a near-surface disposal facility for low-level radioactive wastes. The three subject areas, in the order of presentation, are the site suitability requirements in the proposed 10 CFR Part 61, the site selection process as related to the consideration of alternatives (NEPA requirements), and site characterization activities to be performed in order to develop the site-specific data needed to support a license application and environmental report.

This technical position paper is intended to provide both an explanation of the staff's interpretation of the site suitability and NEPA requirements and recommendations on site characteristics which will aid in demonstration of the suitability of the proposed site. In addition, the technical position paper provides early-on guidance to future applicants to assist them in their site selection and site characterization studies. This paper reflects the staff's position, at this time, on these subjects. If an applicant wishes to consider alternative approaches to site selection and site characterization, the staff will review these on a case-by-case basis.

Site Suitability Requirements

Site suitability requirements for land disposal of low-level radioactive waste are presented in Section 61.50 of the proposed rule. Several of the site suitability requirements identify site characteristics which will be present at any proposed near-surface disposal facility; however, the majority of the site suitability requirements identify site characteristics which will not be present. The site suitability requirements are intended to function collectively with requirements on site design, facility operation, site closure, waste classification and segregation, waste form and packaging, and institutional controls to help assure isolation of the low-level radioactive wastes for the duration of the radiological hazard and to provide stability of the disposal site after closure.

The staff fully expects that the site characteristics of any proposed near-surface disposal facility will make a significant contribution to the isolation of low-level radioactive wastes and the stability of the disposal site after closure. Since license applications are anticipated for near-surface disposal facilities in several different geographical areas exhibiting a wide range of geologic, hydrologic, meteorologic, and climatic conditions, the staff recognizes that the contribution of the site characteristics may vary from site to site. A disposal site with outstanding site characteristics may require less reliance on design features and facility operation than a disposal site with adequate site characteristics.

The staff, in its review of a license application, will emphasize the long-term contribution of the site characteristics because the reliance which can be placed on other subject areas, such as design features, waste form and packaging, and institutional controls, will decrease with increasing time after site closure. Tradeoffs related to the degree of reliance placed on site characteristics and the other subject areas should be made on the side of long-term contribution to the public health and safety as opposed to short-term convenience or benefits.

The site suitability requirements are minimum technical requirements related to the geologic, hydrologic, and demographic characteristics of a disposal site. The staff fully anticipates that any proposed disposal site will meet these minimum technical requirements. The staff foresees very few instances where proposed disposal sites not meeting the minimum technical requirements would be acceptable. Such sites would be evaluated on a site-by-site basis and would require that an exception to the rule be granted.

The specific site suitability requirements in Section 61.50 of the proposed rule are as follows:

1. The disposal site shall be capable of being characterized, modeled, analyzed and monitored.

2. Within the region or state where the facility is to be located, a disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet the performance objectives...

3 Areas must be avoided having known natural resources which, if exploited, would result in failure to meet the performance objectives...

4. The disposal site must be generally well drained and free of areas of flooding or frequent ponding. Waste disposal shall not take place in a 100-year floodplain, coastal high-hazard area or wetland, as defined in Executive Order 11988, Floodplain Management Guidelines.

5. Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or inundate waste disposal units.

6. The disposal site must provide sufficient depth to the water table that ground-water intrusion, perennial or otherwise, into the waste will not occur. The Commission will consider an exception to this requirement to allow disposal below the water table if it can be conclusively shown that disposal site characteristics will result in molecular diffusion being the predominant means of radionuclide movement and the rate of movement will result in the performance objectives... being met. In no case will waste disposal be permitted in the zone of fluctuation of the water table.

7. The hydrogeologic unit used for disposal shall not discharge ground water to the surface within the disposal site.

8. Areas must be avoided where tectonic processes such as faulting, folding, seismic activity, or vulcanism may occur with such frequency and extent to significantly affect the ability of the disposal site to meet the performance objectives... or may preclude defensible modeling and prediction of long-term impacts.

9. Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering occur with such frequency and extent to significantly affect the ability of the disposal site to meet the performance objectives... or may preclude defensible modeling and prediction of long-term impacts.

10. The disposal site must not be located where nearby facilities or activities could adversely impact the ability of the site to meet the performance objectives... or significantly mask the environmental monitoring program.

The first requirement implies that the proposed site should be geologically and hydrologically simple. Since site characterization investigations can sample only a small fraction of the surface area or subsurface volume of the disposal site, site characteristics must be such that these limited investigations can adequately define the site characteristics spatially across the disposal site. Site conditions should be such that well-documented analytical solutions or computer codes are available and applicable for modeling site performance. As a minimum, the modeling of site characteristics, such as infiltration or ground-water flow, should be able to reproduce natural steady-state conditions and perturbed conditions, such as responses to precipitation or stresses introduced by pumping during the site characterization investigations.

Since most modeling tends to homogenize the hydrogeologic units and average the hydrologic properties for such units, the site characteristics should vary within a sufficiently narrow range so that the input to the modeling is representative of the hydrogeologic units and the assumptions underlying the modeling are valid. For example, the hydrogeologic unit used for disposal should not have continuous permeable or impermeable anomalies such as faults or fracture zones, sand lenses, weathered horizons, or karstic features that provide preferential pathways for or barriers to ground-water flow.

The first requirement also implies that natural processes affecting the disposal site should be occurring at a consistent and definable rate such that the modeling of the site will represent both present and anticipatable site conditions after closure. Finally, since monitoring programs can sample only a small fraction of the surface area or subsurface volume of the disposal site, site characteristics must be such that the small number of monitoring points can adequately describe the extent to which radionuclides have migrated from the waste disposal units.

The se ond requirement, related to population growth, is tied to the potential for eventual use of the site. Disposal sites should be located in an area which has low population density and limited population growth potential. Disposal sites should be at least two kilometers from the property limits of the closest population centers. Consideration should be given to the potential for future land use activities, such as residential, industrial, agricultural, and recreational development, that could adversely affect the disposal site. The consideration of future land use for the site and surrounding vicinity should include limitations imposed as conditions of land ownership and zoning restrictions.

The third requirement, related to known natural resources, includes such resources as mineral, coal or hydrocarbon deposits, geothermal energy sources, timber and water resources. The requirement applies to resource recovery that may occur at the ground surface, in the hydrogeologic units used for disposal and isolation, and at greater depths which require excavation or drilling through the disposal units. Potential indirect effects caused by nearby exploitation, such as increased infiltration rates or steepened hydraulic gradients, should be evaluated. The primary concerns with respect to the presence of exploitable natural resources are the likelihood of inadvertent intrusion by a resource exploiter and the effects of resource development on the performance of the site after the period of active institutional control.

The fourth requirement consists of two components. The first component, related to drainage crossing the disposal site, primarily applies to the disposal site after construction of the near-surface disposal facility. However, natural areas of poor drainage or frequent ponding can be indicative of seasonally high ground-water levels and should be so noted by the applicant. In addition, areas of flash flooding, such as arroyos or dry washes, should be avoided. The second component, related to avoidance of the 100-year floodplain, coastal high-hazard area or wetland, implements Executive Order 11988, Floodplain Management Guidelines. This requirement can be applied to the disposal site at the site selection phase.

The 100-year floodplain is defined in the Executive Order as the lowland and relatively flat areas adjoining inland and coastal waters, including floodprone areas of offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year. A coastal high-hazard area is defined as the area subject to high

velocity waters including, but not limited to, hurricane wave wash or tsunamis. Wetlands are defined as those areas that are inundated or saturated by surface water or ground water at a frequency and a duration sufficient to support and under normal circumstances do, or would, support a prevalence of vegetation or aquatic life that requires saturated or seasonally-saturated soil conditions for growth and reproduction. Wetlands generally include swamps, tidal flats, marshes, bogs, and similar areas.

The fifth requirement, related to upstream drainage areas contributing flow across the disposal site, can be applied to the site at the site selection phase. The staff will consider engineering modifications or diversion of natural drainage to lessen potential impacts of the upstream drainage area if these changes are long-term (equivalent to the duration of the radiological hazard) and will not require ongoing active maintenance. The staff anticipates that diversions of perennial streams would not, in most cases, be acceptable. The consideration of upstream drainage areas should include the impact of potential modifications by others to the upstream drainage area, such as land clearing and cultivation or development of roads, which may occur after the near-surface disposal facility is in operation.

The sixth requirement, related to the depth of the water table, indicates that, with few exceptions, near-surface disposal of low-level radioactive wastes will be in unsaturated soil deposits (regolith). Exceptions could include dry disposal in engineered facilities or structures either completely below, partially below, or completely above natural site grade. Alternatively, as indicated in the wording of the requirement, waste disposal may be below the water table at some sites if it can be conclusively shown that site characteristics will result in molecular diffusion being the predominant means of radionuclide movement and the rate of movement will result in the performance objectives being met. In no case, however, should waste disposal occur within the zone marked by fluctuations of the water table.

At sites where disposal will be above the water table, seasonal fluctuations of the water table and capillary fringe both prior and subsequent to waste disposal must be considered. The bottoms of the disposal units must be, at all times, above the saturated zone in order to limit the water contacting the wastes to that small portion which infiltrates through covers in disposal areas. Reducing the contact time of the water with the waste by using freely-draining granular backfill should be considered. In addition, the accumulation of water in the

disposal unit (the bath-tub effect) must be avoided. This can normally be accomplished if the bottom of the disposal unit can drain at least as readily as water can infiltrate into the disposal unit through the cover or sides and if there is no capillary rise of water into the disposal units from the underlying soil deposits.

For sites where disposal will be below the water table, the hydrogeologic unit used for disposal should have hydraulic properties, e.g. hydraulic conductivity and effective porosity, which essentially preclude ground-water flow. The hydraulic conductivity, as tested in-situ, should typically be less than 10^{-6} cm/sec. The effective porosity would be expected to be on the order of 0.01. Hydrogeologic units which meet these conditions generally cannot be tested by normal techniques requiring addition or withdrawal of water in wells. Methods of determining that molecular diffusion is the prevalent mechanism of solute transport include age-dating of ground water by isotopic ratios and radioisotopic methods to show that there has been no active circulation of ground water within the unit during the length of time determined by the age-dating.

The seventh requirement, related to ground-water discharge, stipulates that the hydrogeologic unit used for disposal will not discharge ground water to the ground surface within the disposal site. Surface-water features sustained by ground-water discharge, such as perennial and ephemeral streams, springs, seeps, swamps, marshes, and bogs, should not be present at the proposed disposal site. This requirement will result in a travel time for most dissolved radionuclides at least equal to the travel time of the ground water from the disposal area to the site boundary. In addition, this requirement should provide sufficient space within the buffer zone to implement remedial measures, if needed, to control releases of radionuclides before discharge to the ground surface or migration from the disposal site.

Longitudinal dispersion may result in arrival of a few dissolved radionuclides at a point of interest earlier than calculated solely on the basis of ground-water travel time. However for many radionuclides, the travel time should be longer due to retardation processes.

The staff prefers long flow paths from the disposal site to the point of ground-water discharge in order to increase the amount of decay of the radionuclides, increase the hydrodynamic dispersion within the aquifer, and increase the likelihood of retardation of reactive radionuclides in the aquifer. In reviewing licensing applications, the staff will rely primarily on radionuclide decay and secondarily on hydrodynamic dispersion

within the aquifer to determine if estimated concentrations will be less than the acceptable limits. Retardation processes will be used as a margin of safety to offset the uncertainty in the data and analyses. However, the applicant may propose to consider each of the processes. The degree of reliance placed by the applicant on each of the three processes should be reflected in the methods of testing used during the site characterization investigations, as discussed later in the technical position paper.

The eighth and ninth requirements, related to tectonic and geomorphic processes, respectively, can be applied to the disposal site at the site selection phase. These requirements relate primarily to the stability of the disposal site. The natural processes affecting the disposal site should be occurring at a consistent and definable rate. In addition, these processes should not occur at a frequency, rate, or extent which can significantly change the stability of the site or the ability of the disposal site to isolate low-level radioactive wastes during the duration of the radiological hazard (approximately 500 years). Changes which occur due to these processes should not invalidate the results of any modeling and prediction of long-term impacts.

The tenth requirement, related to effects of nearby facilities or activities, is included so that the evaluation of any proposed disposal site will include not only the impacts of that disposal site on its surroundings but also the impacts of the surroundings on the disposal site. For example, damming of downstream rivers, blasting associated with quarrying activities, subsidence and/or earth-fissuring caused by ground-water withdrawals, and ground-water rises associated with heavy irrigation may adversely affect the ability of the site to meet the performance objectives. Nearby sources of airborne radionuclides, drift from cooling towers at nearby electrical generating stations or other industries, adjacent hazardous waste disposal facilities, and injection of water and/or liquid wastes upgradient from the disposal site may adversely affect the ability to monitor the performance of the disposal site. In cases of co-located facilities, the monitoring programs for the facilities should be able to identify the source and differentiate between the releases of the separate facilities. In addition, the monitoring programs should provide adequate data to identify mitigative measures, if needed, for the separate facilities.

Site Selection

The site selection process used by any applicant, individual state, or regional compact of states may vary considerably due to a wide variety of factors such as geographical distribution of low-level radioactive waste generators; diverse geologic, hydrologic, meteorologic, climatic, ecologic, and socioeconomic settings; and provisions on site selection in the compact charters. However, the NRC staff anticipates that the site selection processes followed in separate applications will share the same basic steps.

The first step will consist typically of defining the region of interest, such as the area within the geographic boundaries of an individual state or regional compact. The second step will consist of screening the region of interest to identify potential sites. In the third step, the potential sites will be screened against a common set of criteria, including the minimum technical requirements in 10 CFR Part 61 and the environmental standards in 10 CFR Part 51. The third step is envisioned as a coarse screening process which will identify a slate of candidate sites for more detailed review.

The fourth step will consist typically of a detailed review of the slate of candidate sites identified through the coarse screening. The first four steps will rely primarily upon available reconnaissance-level information. The primary differences between the steps will be the level of detail of the review and the inclusion of additional items to be evaluated in each step. For example, the fourth step may include items such as conceptual designs, preliminary cost estimates, release scenarios, and pathway studies which were not included in the previous steps. The fourth step will conclude with the selection of a preferred site from among the candidate sites.

In some cases, limited investigations of site characteristics at some or all of the candidate sites may be needed during the fourth step to evaluate these additional items and to adequately distinguish between the candidate sites such that a preferred site can be identified. However, the major portion of the site characterization studies will be performed at the preferred site after selection from among the candidate sites. Only if the detailed site characterization studies identify unanticipated adverse conditions at the preferred site would detailed investigations be performed at more than one site.

The NEPA regulation requires a comparison of alternatives to the proposed action. In meeting this regulation, there should be comparison between the preferred site and two or three viable alternative sites selected from among the candidate sites. Viable alternative sites can be defined as sites that, although not selected as the preferred site, would meet the minimum technical requirements and would reasonably be expected to meet the performance objectives. To the extent that the diversity of candidate sites will permit, the comparison between the preferred and alternative sites should include consideration of different geologic media, different conceptual designs afforded by the alternative sites, different environmental impacts associated with each site in the comparison, and projected cost differences.

In addition, the comparison of alternatives should include consideration of the different conceptual designs considered for the preferred site and available actions for mitigating environmental impacts at the preferred site. This comparison of alternatives should stop at the level where there is no difference between the alternatives in terms of environmental impact.

Site Characterization

Site characterization is defined, for purposes of this technical position paper, as the program of investigations and tests, both in the field and laboratory, undertaken to define the site characteristics affecting the isolation of the low-level radioactive wastes, the long-term stability of the disposal site, and the interactions between the disposal site and its surroundings. The evaluation of available reconnaissance-level data during the site selection process should serve as a basis for design of the site characterization program. Data from both site selection and site characterization will be required to support a license application and environmental report (standard format and content guides are in preparation).

Site characterization studies should be performed after selection of a preferred disposal site and prior to submittal of a license application and environmental report for a proposed near-surface disposal facility. As indicated previously, the staff anticipates that, in most cases, site characterization studies will be performed only at the preferred disposal site.

The overall objective of site characterization is to investigate the characteristics of the preferred disposal site to the extent needed to 1) support a license application and environmental report, and 2) permit an independent evaluation of the proposed near-surface disposal facility by the staff. This independent evaluation will, as stated previously, include both consideration of public health and safety (10 CFR Part 61) and compliance with NEPA (10 CFR Part 51).

Specific objectives of site characterization are to develop the technical information needed for:

1. demonstration that the performance objectives and the minimum technical requirements on site suitability will be met;

2. evaluation of the ability of the site characteristics to contribute to isolation of the low-level radioactives wastes;

3. design of the near-surface disposal facility;

4. identification of interactions between the site characteristics and the low-level radioactive waste and waste containers;

5. establishment of data collection points and a baseline of data for some portions of the site monitoring program; and

6. identification of potential environmental impacts resulting from construction, operation, and closure of the near-surface disposal facility.

One problem experienced at several existing low-level radioactive waste disposal facilities has been the identification of site conditions during site operations which were not adequately investigated and evaluated during the site characterization programs. In several instances, the additional information has raised questions related to the ability to adequately model and monitor the potential migration of radionuclides in the site ground-water systems. Therefore, the staff takes the position that the site characterization program for any proposed near-surface disposal facility should be planned, implemented, and analyzed by a technical staff with professional expertise and experience in each of the various disciplines in the following discussion. This technical staff may be internal to the applicant's organization or may retained by standard consulting arrangements.

The site characterization program for any proposed disposal site must be tailored to the characteristics of the specific disposal site. Hence, site characterization programs will vary from site to site. In addition, the site characterization program for any site can be expected to be revised as the program progresses and more site-specific information is obtained.

Many of the site characteristics measured during the site characterization program will vary with time. Time-variant site characteristics may include meteorological characteristics such as temperature, wind direction and precipitation; hydrological characteristics such as soil moisture content, ground-water levels, and ground-water quality; and ecological characteristics such as the presence of migratory species. Data on some of these time-variant site characteristics may be available from measurements or surveys at regional recording stations. However, some parameters may require site-specific measurements at such frequency and duration so as to adequately define the seasonal range of values.

For example, the staff anticipates that data needed to determine the site water budget and fluctuations of ground-water levels would typically necessitate a minimum one-year period of measurement at the proposed disposal site. This minimum one-year period of record should be supplemented, where possible, with regional data covering a longer time period.

The staff anticipates that the licensing process can be expedited if applicants submit their site characterization plans for review and discussion prior to initiating site characterization. This early-on review and discussion serves as a pre-licensing consultation with the staff. In this manner, any concerns that the staff has related to the specific characteristics of the proposed disposal site or the site characterization program can be identified and incorporated as appropriate into the program. Early-on review and discussion can benefit the applicant by identifying those site characteristics that will or will not need to be investigated, determining appropriate methods of investigation to be used for those which are needed, and identifying the appropriate level of detail, such as the size of the study area, the depth of borings, the hydrogeologic units to be investigated, and points of interest for determination of potential releases of radionuclides. Early-on review and discussions can also benefit the applicant by reducing the likelihood of delays while additional data are collected and by avoiding increased costs associated with remobilizing the study team. The staff recommends that these pre-licensing discussions continue on a frequent basis during implementation of the site characterization program.

The proposed rule requires that the applicant conduct a pre-operational monitoring program to provide a baseline of data on site characteristics. Data collection points established in the site characterization studies for this pre-operational monitoring program should, to the extent practicable, be located, designed, and constructed for use throughout the periods of operation, post-closure observation and maintenance, and institutional control for the near-surface disposal facility (approximately 150 years). In this manner, there will be a common data set from which potential health and environmental impacts can be identified, long-term effects of changes in site characteristics on radionuclide migration and stability of the disposal site can be evaluated, and the need for mitigating measures can be determined. Portions of the site characterization studies that the staff recommends be incorporated into the site monitoring program have been identified in the following text.

The staff has attempted to be comprehensive in identifying, in this technical position paper, specific types of site characterization activities that may be needed at proposed disposal sites. To supplement the technical position paper, the NRC has an inter-agency agreement with the U.S. Army Corps of Engineers, Waterways Experiment Station to provide NUREG reports on the recommended parameters and methods for characterizing low-level radioactive waste disposal sites. These NUREG reports should be available in June and August, 1982, respectively. In addition, the NRC and Oak Ridge National Laboratory will convene a symposium on site characterization and site monitoring programs in June, 1982.

Meteorology. Meteorological data are needed primarily for three analyses. These are the determination of a water budget for the disposal site, the analysis of the airborne pathway, and the determination of the frequency, probability and potential consequences of severe meteorological phenomena.

Regional meteorological data from recording stations near the proposed disposal site will typically be analyzed during the site selection process for extreme meteorological events such as hurricanes, tornadoes, and thunderstorms. The analyses should include the frequency and probability of occurrence, return intervals, predominant direction, and measured extremes for wind speed and precipitation.

For analysis of the site water budget and the airborne pathway, site-specific meteorological data should be collected during the site characterization program. The site characterization program should include measurements of the amount, type, and temporal distribution of precipitation; dates and depth of frost penetration; and dates and thickness of snow cover. The site characterization program should also include continuous recordings of air and soil temperature, wind speed, wind direction, surface humidity, dew point, and atmospheric pressure. Air and soil temperatures are typically needed at several levels up to one meter above or below the ground surface, respectively. Since atmospheric stability is typically estimated from wind speed and wind direction fluctuations at about 2 and 10 meters, these parameters should be measured continuously at both levels.

The staff anticipates that a minimum record of one year of site-specific meteorological data will be collected during site characterization. Data collected from the on-site meteorological station should be compared to historical records from nearby recording stations which have similar topographical and hydrometeorological settings in order to determine whether the site-specific data fit within the regional data and to what extent this one-year period of record represents a "typical" weather year when compared to the historical record. The longer-duration, regional data base may be useful in extending the site-specific data base for use in long-term analyses.

The on-site meteorological station should be incorporated into the site monitoring program in order to extend the length of record of site-specific data collected during the site characterization studies. The increased record of site-specific data can then be used to verify data used in the analysis of water budget and atmospheric dispersion.

Surface Water. Site-specific surface-water data are needed to demonstrate that the technical requirements related to surface-water hydrology in the proposed rule are met. Surface-water data are also needed for analysis of the surface-water pathway and for design of the near-surface disposal facility. Specific design analyses include potential flooding of the disposal site by off-site streams, design of the site drainage system, potential inundation of the waste disposal areas during maximum precipitation events, and potential erosion within the disposal site.

Site characterization activities related to surface-water hydrology will include not only the site, but also the upstream drainage area contributing flow across the site and the downstream drainage area to a distance of approximately 10 kilometers.

The site characterization program should include collection of the reconnaissance-level information needed for determining the extent of the 100-year floodplain (guidance in Executive Order 11988), determining flood-flow frequencies (guidance in the U.S. Water Resources Council Bulletin 17A), and determining the Probable Maximum Flood (PMF) and the Probable Maximum Precipitation (PMP) for the site (guidance in NRC Regulatory Guide 1.59, Design Basis Floods for Nuclear Power Plants).

Site characterization studies should also include aerial photography and topographic mapping of the site and adjacent drainage areas in order to identify features such as drainage divides, sizes of drainage areas, surface gradients and abrupt changes therein, areas of internal or closed drainage, areas of flash flooding, areas of scour or sedimentation, and areas suitable for future impoundments. Topographic mapping of the disposal site and upstream drainage area should be at a scale on the order of 1:2400, with a contour interval on the order of 1 foot. For downstream drainage areas, 7 1/2- or 15-minute topographic maps available from the U.S. Geological Survey (USGS) should suffice. Survey control for the site topographic mapping should be coordinated with the survey control requirements for marking the boundaries and locations of each disposal unit. This requirement calls for establishing three permanent survey control points, referenced to USGS or National Geodetic Survey survey control stations, at the disposal site.

Site characterization studies should also include measurements of runoff coefficients, infiltration rates, and channel characteristics such as slope, profile, cross-section, and roughness for drainage systems crossing the site in order to determine, where appropriate, the flow velocities, depths, volumes, and durations. Parshall flumes and sediment samplers should be installed, where appropriate, to determine the rate of erosion of site soil deposits under varying gradients and ground conditions. Particle-size distribution, soil cohesion, and soil dispersion tests should be performed, as needed, to determine the erodibility of site soil deposits.

The site characterization program should also include an inventory of existing surface-water users and municipal supplies within approximately 10 kilometers downstream of the site in order to determine the nearest surface-water users and the nearest municipal supply relying on surface water. For these locations, the inventory should include the location, type, and amount of use; source of supply; type of intake; and surface-water quality data as submitted to the EPA periodically for certification.

Ground Water. Site-specific ground-water data are needed to determine that the technical requirements related to ground-water hydrology are met. Ground-water data are also needed for analysis of the ground-water pathway and for design of the near-surface disposal facility.

The staff considers the ground-water pathway to be the most significant pathway for migration of radionuclides at humid sites. At arid sites, the staff considers the movement of soil moisture and vapor to be the most significant pathway for migration of radionuclides. At either type of site, the staff considers the contact of soil moisture with the waste containers and waste to be the major mechanism for potential release of radionuclides. Therefore, the discussion of ground water in this technical position paper is more detailed than discussions of the other technical areas.

The radius of ground-water studies during site characterization should vary depending upon the types of aquifers underlying the proposed disposal site. Shallow, unconfined (water table) aquifers may require a study area radius on the order of several kilometers to encompass the ground-water flow system and off-site ground-water users. Confined (artesian) aquifers may require a study area radius on the order of several tens of kilometers to encompass the ground-water flow system and off-site ground-water users. In either case, the staff anticipates that the off-site data can be obtained by review of available reconnaissance-level information.

The site characterization studies should include an inventory of existing ground-water users within approximately two kilometers of the site. For these ground-water users, the inventory should include the location, type, and amounts of use; hydrogeologic unit used; typical well construction details; and ground-water quality. The inventory should include both ground-water wells and water users at points of ground-water discharge, e.g., springs. The inventory should identify,

for use in the ground-water pathway analysis, the nearest downgradient ground-water users and the nearest municipal supply relying on ground water.

The site characterization studies should identify all significant hydrogeologic units underlying the site to a depth on the order of 30 meters below the level of waste disposal. The exact depth of investigation should be determined on a site-specific basis using reconnaissance-level information collected during the site selection process. The reconnaissance-level information should be sufficient to provide necessary ground-water data for the hydrogeologic units more than 30 meters below the level of waste disposal.

The site characterization investigations of significant hydrogeologic units overlap with geologic and tectonic studies described in a later section. Together they should identify the lithology, thickness, lateral extent, continuity, inclination, areas and modes of recharge and discharge, hydraulic properties, head, hydrochemistry, hydraulic communication with adjacent hydrogeologic units, and interrelationship with surface-water bodies for the significant hydrogeologic units underlying the site. The studies should also investigate the presence of secondary permeability, such as solution features, or other preferential pathways, such as fault zones or joint systems. In addition, the studies should investigate the presence of flow barriers, such as fault zones or dikes.

The site characterization studies should develop data needed to describe the occurrence and movement of water in both the unsaturated and saturated zones. The parameters which govern the rate, direction, and velocity of soil moisture movement and ground-water flow should be measured. These parameters include hydraulic conductivity, head, hydraulic gradient, effective porosity, specific storage, saturated thickness and compressibility. The site characterization studies should establish mean and median values, ranges of values, and spatial and temporal variability for these parameters for the significant hydrogeologic units. The data collection points for moisture content and head measurements (above and below the water table) should be appropriately located in three dimensions within the separate hydrogeologic units to establish the boundary conditions for modeling.

The identification of head distribution, both vertically and spatially, is particularly significant since it can be used for many purposes, including defining recharge/discharge areas, variations in hydraulic conductivity, and hydraulic communication with adjacent hydrogeologic

units. In addition, the head distribution is the most readily useable parameter for determining the ability of models to reproduce natural steady-state conditions or perturbations on the systems modeled.

Hydraulic conductivity may vary significantly above the water table as the moisture content and head change. Site characterization studies should define the relationship between these parameters, including the hysteresis. The water-holding parameters for soil above the water table, such as specific retention, field capacity, and wilting point should also be measured.

The staff anticipates that head and moisture content will be measured for a minimum period of one year and will be compared to historic records of precipitation, moisture content, and water levels in the same or similar aquifers. In this manner, the applicant can estimate seasonal and long-term fluctuations of moisture content and head in the hydrogeologic units and determine the extent to which the one-year record of site-specific data represents a "typical" water year. The frequency of measurement should reflect the mode of recharge of the hydrogeologic unit, with more frequent (weekly) measurements in unconfined units responding to precipitation events and less frequent (monthly) measurements in confined units not directly responding to precipitation events.

The site characterization studies should also include collection of ground-water chemistry data. Parameters measured should include indicators of drinking water quality and the direction of flow, areas of recharge, and age of the ground water in the flow system. Other parameters which may affect the solubility of waste leachates, such as by causing changes in oxidation states and/or precipitation from solution, should also be measured. Major inorganic constituents, dissolved oxygen, and other characteristic properties, such as temperature and pH, should be included in the site characterization studies. Major organic constituents, such as total organic carbon and chemical oxygen demand, may also be included. Age-dating techniques, such as tritium, oxygen-18/oxygen-16 ratio, carbon-13/carbon-12 ratio, carbon-14, and chlorine-36, should be included as appropriate for sites where disposal will be below the water table and molecular diffusion must dominate the flow system.

The staff anticipates that ground-water chemistry will be measured, at least quarterly, for a minimum period of one year and will be compared to historic records, if available. In this manner, the applicant can estimate seasonal and long-term fluctuations of ground-water chemistry as a background for continued monitoring of key indicators of

ground-water quality and leachate (radiological and non-radiological) migration.

For those sites where hydrodynamic dispersion and/or retardation will be considered in the transport analyses, the site characterization studies should include determination of the coefficient of dispersion and/or the distribution coefficients for radionuclides of interest in the ground water-soil system through which transport is expected to occur. The degree of reliance placed upon hydrodynamic dispersion (based on the coefficient of dispersion) or retardation (based on the distribution coefficient) should determine the methods used to quantify these values.

For sites where hydrodynamic dispersion is a primary mechanism for demonstrating that potential concentrations will be within acceptable limits, field dispersivity tests may be necessary to quantify the coefficient of dispersion. For sites where ground-water travel time is the primary mechanism and hydrodynamic dispersion is a secondary mechanism for demonstrating that potential concentrations will be within acceptable limits, the coefficient of dispersion may be estimated based on values reported in the literature or derived by empirical relationships.

For sites where retardation processes are relied upon to demonstrate that potential concentrations will be within acceptable limits, the distribution coefficients for the specific radionuclides should be determined by column tests, using site-specific ground water and undisturbed soil samples, or by field tracer tests.

Geology The site selection studies should have included the development of a regional geologic framework, including the stratigraphy, tectonics, structure, physiography, and geomorphology of the region surrounding the proposed site. Seismic and volcanic risks should have been evaluated in this regional geologic framework. The staff anticipates that regional information may be obtained from published sources, such as the various USGS report series, state geological survey reports, and other professional publications. Site-specific geologic and hydrogeologic investigations should be defined using the understanding gained by developing the regional geologic framework.

Stratigraphic data will typically be generated by several types of site characterization investigations. The staff anticipates that no single technique can adequately characterize the site stratigraphy.

The first type consists of surface mapping of geologic and hydrologic features of the site. This mapping will supplement the site topographic mapping and should assist in planning the other types of investigations. Surface mapping of the site geology should be on a scale consistent with the site topographic maps previously mentioned. Terminology used should be consistent with the accepted usage of the state geological survey or the USGS. The second type consists of exploratory boreholes with detailed descriptions and laboratory testing of core samples. To the extent practicable, the boreholes should be located, drilled, and sampled for use in the hydrogeologic and geomechanical investigations and the site ground-water monitoring program. The third type of investigation, surficial geophysical surveys, should provide subsurface information between boreholes. These surficial geophysical surveys, such as electrical resistivity or seismic refraction, should define the vertical and horizontal extent of the site stratigraphic units, heterogeneities, such as sand lenses within the units, and the surface of the water table.

The fourth type of investigation consists of borehole geophysical logging. A wide variety of techniques are available. The techniques used are primarily dependent upon the required information, the types of soil deposits, and the location of the water table. A typical suite of borehole geophysical techniques for a proposed disposal site may include spontaneous potential, natural gamma, gamma-gamma, neutron, resistivity, and gamma-ray spectrometry. The fifth type of investigation, test pit or slit trench excavation, should provide large-scale exposures of the stratigraphic units and design-related information on the excavation characteristic and the material handling properties of the soil deposits. Test pit or slit trench excavations will not, in most cases, be suitable for waste disposal after operations begin due to the effects of weathering on the exposed soil deposits. Since the design of the disposal facility will typically be determined by the results of the site characterization investigations, any test pit or slit trench excavations may also not be suitable for waste disposal due to incompatability with the site drainage system or other design features.

Lithologic investigations will range from lithologic descriptions based on visual observations of soil samples and exposures in test pits to laboratory tests designed to produce data on characteristics such as clay mineral composition, carbonate content, particle-size distribution, moisture content, porosity, permeability, bulk density, and ion-exchange capacity.

Visual observation of core samples and exposures in test pits or slit trenches should reveal any primary structures (such as joints or shear surfaces), depositional features (such as localized channel deposits, varves, cross-bedding, or graded-bedding), or weathering (pedalogic) profiles which may result in significant anisotropy of properties important to ground-water flow and solute transport.

Structural geologic investigations of the site should concentrate on joints and other fractures present in the hydrogeologic unit(s) used for the disposal and isolation of the waste. These joints or other fractures may be of either tectonic or nontectonic origin (e.g., cracking caused by subsidence, dessication, or glacial unloading). Such physical discontinuities may act as planes of weakness for slope failure or as preferential pathways for fluid flow and solute transport. In fractured media, studies should be performed to define fracture spacing, continuity, roughness, and aperture for analyses of slope stability and modeling of fluid flow and solute transport.

Geomorphic investigations should include systematic analysis of landforms to give indirect evidence of destructive geomorphic processes. For example, over-steepened valleys, landslides, rockslides, and sharply-incised stream valleys may be evidence of slope instability or excessive erosion rates.

Geomechanics. Site characterization studies related to geomechanics will provide data for major design-related analyses, such as slope stability, cover integrity, erosion, compaction characteristics for backfill materials, foundation analyses for any structures housing waste handling or repackaging facilities, gradations for proposed filter materials, and possible interactions between the soil and waste containers. The staff anticipates that many of the design features at the near-surface disposal facility, e.g., covers and backfill for disposal units and filter materials for drains, will employ specially-selected earth materials.

The site characterization studies should be designed such that sufficient and suitable data are available to perform the needed analyses. The analyses should include consideration of both temporary and final site slopes and grades. Laboratory studies should include classification and index tests, such as the Unified Soil Classification System and Atterberg limits, respectively. These may supplement lithologic descriptions of soil samples collected during subsurface geological investigations. The coefficient of consolidation, minimum density, and void ratio of backfill should be determined as needed for settlement analysis. Organic content, particle-size distribution, Atterberg limits, and

moisture-density relationships (such as those determined using the Modified or Standard Proctor tests) should be determined for design of the backfill and the covers. Cohesive soils used in the covers will be subject to cycles of wetting and dessication and therefore should be tested for shrink-swell characteristics and clay mineralogy. In some cases, freezing characteristics of the soil may be needed to determine freeze/thaw effects, particularly changes in volume and hydraulic conductivity. In addition, the cohesion, angle of internal friction, and unit weight (saturated and unsaturated) of the soils may be needed for analyses of slope stability for natural, cut, or fill slopes. Additional parameters may be needed, depending on the type of soil and the method of analysis.

Particle-size distribution, dispersive characteristics and cohesion of the surficial soils and covers should be determined to assist in the analysis of erosion resistance. Parameters such as the coefficient of consolidation, void ratio, cohesion, angle of internal friction, limit pressure, deformation modulus, or penetration resistance (as measured with the Standard Penetration Test or Cone Penetrometer) should be determined as appropriate for the soil types and method of analysis used to determine the bearing capacity of the subgrade soils and the settlement of structures. Index properties, such as unit weights, Atterberg limits, organic content, and particle-size distribution may also be needed.

Particle-size analysis of the in-situ soils and proposed filter materials may be necessary to demonstrate the effectiveness of proposed subdrains. Subdrains should have a particle-size distribution which readily allows passage of water without clogging due to transport of fine material from the adjacent soil units. Analysis of the corrosivity of the fill to be used around the waste containers may necessitate the determination of soil resistivity, pH, moisture content, and oxidation-reduction potential.

Air Quality. The site characterization program should include analyses of on-site air quality for use in estimating facility-generated radiological and non-radiological impacts on air quality and in performing atmospheric transport/dispersion modeling. The air quality studies are especially important if the applicant plans atmospheric releases of potential radiological or non-radiological contaminants, such as through the use of an evaporator or incinerator.

Air quality parameters measured in the site characterization program should define the level of airborne radionuclides contributed by atmospheric fallout, natural radiation released from the soil, and agricultural activities such as spray application of fertilizers or insecticides. Suspended particulates should also be measured during the site characterization studies.

The measurement of air quality parameters should provide at least a one-year record of site-specific information. These data will serve as a baseline for the site monitoring program, and, the data collection points used during site characterization should be incorporated into the site monitoring program.

Ecology. The site characterization studies should include ecological surveys of the proposed disposal site needed for sections of the environmental report dealing with terrestrial and aquatic ecology. These sections will include a description of the ecology of the site and site vicinity, an analysis of ecological impacts, and identification of proposed mitigating measures (if necessary).

The ecological survey should encompass a radius on the order of 5 kilometers from the disposal site. This program should be geared toward assembling an accurate, site-specific inventory of flora and fauna. Sampling for the ecological survey should be conducted for a minimum period of one year on a quarterly basis to determine seasonal variations (where appropriate) of both terrestrial and aquatic species. The survey should utilize established scientific methods for surveying, data retrieval, and data reduction. The ecological survey should include consultation with local authorities about available published data on local biota which can then be used to augment the field work.

The use of the site vicinity as breeding grounds or by migratory species should be included in the ecological survey. The survey should include an identification of important species. A definition of important species is provided in NRC Regulatory Guide 4.2, Section 2.2, Ecology. The survey should also address the distribution, habitats, and ecological interrelationships of the important species.

The number, extent and distribution of livestock, and crops should also be surveyed. Finally, the ecological survey should be used to relate the site vicinity to the surrounding region, noting any unique characteristics of the site vicinity.

Land Use and Cultural Resources. Surveys of land use and cultural resources are necessary for the analysis of impacts of the near-surface disposal facility to be included in the environmental report.

The land use survey may be conducted largely from existing published materials such as local land use plans, aerial photography, topographic maps, or other sources. The land use survey, therefore, will most likely have been included in the site selection process. However, field work may be necessary to verify current conditions or to answer any questions that arise during the site selection process. The survey should include land use patterns within a radius of approximately 10 kilometers from the site. Land uses should be classified as agricultural, residential, industrial, woodland, commercial, institutional, transportation, special management areas (parks, scenic areas, military reservations, etc.) or other use categories and should be mapped accordingly. The applicant should review and describe zoning categories of the site and the 10 kilometer radius of the study area. Trends in land use in the site vicinity should also be identified.

Site characterization studies should also include an inventory of residences within approximately two kilometers of the site and population centers within a radius on the order of 10 kilometers from the site. This inventory is needed as input to the analysis of the airborne pathway. The inventory should include the distance and direction of the residence or population center from the site and a description of any intervening topographic features which may significantly affect the dispersion analyses. For the population centers, the inventory should also include the number of persons and areal size of the population center.

A cultural resources survey of the site and surrounding region to a radius of approximately 10 kilometers from the site should also be performed. This survey should be coordinated with the State Historic Preservation Officer and should attempt to identify, via literature review, field reconnaissance, and limited surface testing (if necessary), the potential for encountering cultural resources of significance as defined by federal, state, and/or local historic preservation laws. Both historic and pre-historic resources should be considered in planning and executing the survey.

The cultural resources survey of the disposal site should include mapping of identified cultural sites and an evaluation of the potential of any cultural site for inclusion on the National Register of Historic

Places or in any state or local registers. The survey of the area surrounding the site should include a listing of cultural sites within a radius of approximately 10 kilometers which are currently listed or nominated for inclusion on the National Register of Historic Places, the National Registry of Natural Landmarks, or any similar state or local lists.

Socioeconomics. A description of the socioeconomic environment is needed for the analysis of the facility impacts in the environmental report. The socioeconomic study may be conducted largely from existing published materials. The socioeconomics study, therefore, will most likely have been included in the site selection process. However, the applicant may need to survey the study area, usually defined on the basis of political jurisdictions such as counties, to establish data such as population, labor availability, labor skills, transportation, historic commuting patterns, school systems, health system, public safety system, utilities, tax base, commerce, and housing stock.

The staff anticipates that the project work force will have the greatest socioeconomic impact. This project work force is not expected to be large and, therefore, the impacts from a near-surface disposal facility are likewise not expected to be large in most cases. However, the potential for impacts may vary from site to site as a function of project size, existing socioeconomic conditions, and the ability of the subject region to accommodate a temporary or permanent influx of workers and their families.

A sociocultural analysis may also be appropriate. In such cases, attitudinal surveys should be performed during site characterization. Sociocultural dimensions to be surveyed may include commmunity cohesion, family stability, local attitudes and lifestyle, and prevailing community problems. As in the socioeconomic analysis, the project characteristics should be superimposed on the sociocultural dimensions to identify project-related impacts such as changes in community composition, marital and family status, cultural values, and other quality of life indicators.

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The staff provides an expanded interpretation of the site suitability requirements in the proposed rule 10 CFR Part 61, a description of the anticipated site selection process, and a detailed discussion of the site characterization program needed to support a license application and environmental report. The paper provides early-on guidance to prospective applicants in these three subject areas.

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