

C.I.2 Site Characteristics

This chapter of the Final Safety Analysis Report (FSAR) should provide information on the geological, seismological, hydrological, and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distribution and land use and site activities and controls. The purpose is to indicate how these site characteristics have influenced plant design and operating criteria and to show the adequacy of the site characteristics from a safety viewpoint.

C.I.2.1 Geography and Demography

C.I.2.1.1 Site Location and Description

C.I.2.1.1.1 Specification of Location

The location of each reactor at the site should be specified by latitude and longitude to the nearest second and by Universal Transverse Mercator Coordinates (Zone Number, Northing, and Easting, as found on United States Geological Survey (USGS) topographical maps) to the nearest 100 meters. The USGS map index should be consulted for the specific names of the 7½ minute quadrangles that bracket the site area. The State and county or other political subdivision in which the site is located should be identified, as well as the location of the site with respect to prominent natural features such as rivers and lakes, man-made features such as industrial, military, and transportation facilities.

C.I.2.1.1.2 Site¹ Area Map

A map of the site area of suitable scale (with explanatory text as necessary) should be included. It should clearly show the following:

- (1) The plant property lines. The area of plant property in acres should be stated.
- (2) Location of the site boundary. If the site boundary lines are the same as the plant property lines, this should be stated.
- (3) The location and orientation of principal plant structures within the site area. Principal structures should be identified as to function (e.g., reactor building, auxiliary building, turbine building).

¹“Site” means the contiguous real estate on which nuclear facilities are located and for which one or more licensees has the legal right to control access by individuals and to restrict land use for purposes of limiting the potential doses from radiation or radioactive material during normal operation of the facilities.

DG-1145, Section C.I.2 - Site Characterization

- (4) The location of any industrial, military, transportation facilities, commercial, institutional, recreational, or residential structures within the site area.
- (5) A scaled plot plan of the exclusion area (as defined in 10CFR100.3), which permits distance measurements to the exclusion area boundary in each of the 22½ degree segments centered on the 16 cardinal compass points.
- (6) A scale that will permit the measurement of distances with reasonable accuracy.
- (7) True north.
- (8) Highways, railroads, and waterways that traverse or are adjacent to the site.
- (9) Prominent natural and man-made features in the site area

C.I.2.1.1.3 Boundaries for Establishing Effluent Release Limits

The site description should define the boundary lines of the restricted area (as defined in 10 CFR 20.1003) and should describe how access to this area is controlled for radiation protection purposes, including how the applicant will be made aware of individuals entering the area and will control such access. If it is proposed that limits higher than those established by § 20.1301 (and related as low as is reasonably achievable provisions) be set, the information required by Appendix I to 10 CFR Part 50, should be submitted. The site map discussed above may be used to identify this area, or a separate map of the site may be used. Indicate the location of the boundary line with respect to the water's edge of nearby rivers and lakes. Distances from plant effluent release points to the boundary line should be clearly defined.

C.I.2.1.2 Exclusion Area Authority and Control

C.I.2.1.2.1 Authority

The application should include a specific description of the applicant's legal rights with respect to all areas that lie within the designated exclusion area. The description should establish, as required by paragraph 100.3(a) of Part 100, that the applicant has the authority to determine all activities, including exclusion and removal of personnel and property from the area. The status of mineral rights and easements within this area should be addressed.

If ownership of all land within the exclusion area has not been obtained by the applicant, those parcels of land not owned within the area should be clearly described by means of a scaled map of the exclusion area, and the status of proceedings to obtain ownership or the required authority over the land for the life of the plant should be specifically described. Minimum distance to and direction of exclusion area boundaries should be given for both present ownership and proposed ownership. If the exclusion area extends into a body of water, the application should specifically address the bases upon which it has been determined that the authority required by paragraph 100.3 of Part 100 is or will be held by the applicant.

C.I.2.1.2.2 Control of Activities Unrelated to Plant Operation

Any activities unrelated to plant operation which are to be permitted within the exclusion area (aside from transit through the area) should be described with respect to the nature of such activities, the number of persons engaged in them, and the specific locations within the exclusion area where such activities will be permitted. The application should describe the limitations to be imposed on such activities and the procedure to be followed to ensure that the applicant is aware of such activities and has made appropriate arrangements to evacuate persons engaged in such activities, in the event of an emergency.

C.I.2.1.2.3 Arrangements for Traffic Control

Where the exclusion area is traversed by a highway, railway, or waterway, the application should describe the arrangements made or to be made to control traffic in the event of an emergency.

C.I.2.1.2.4 Abandonment or Relocation of Roads

If there are any public roads traversing the proposed exclusion area which, because of their location, will have to be abandoned or relocated, specific information should be provided regarding authority possessed under State laws to effect abandonment; the procedures that must be followed to achieve abandonment; the identity of the public authorities who will make the final determination; and the status of the proceedings completed to date to obtain abandonment. If a public hearing is required prior to abandonment, the type of hearing should be specified (e.g., legislative or adjudicatory). If the public road will be relocated rather than abandoned, specific information as described above should be provided with regard to the relocation and the status of obtaining any lands required for relocation.

C.I.2.1.3 Population Distribution

Population data presented should be based on the latest census data. The following information should be presented on population distribution.

C.I.2.1.3.1 Population Within 10 Miles

On a map of suitable scale that identifies places of significant population grouping such as cities and towns within a 10-mile radius, concentric circles should be drawn, with the reactor at the center point, at distances of 1, 2, 3, 4, 5, and 10 miles. The circles should be divided into 22-1/2-degree segments with each segment centered on one of the 16 compass points (e.g., true north, north-northeast, northeast). A table appropriately keyed to the map should provide the current residential population within each area of the map formed by the concentric circles and radial lines. The same table, or separate tables, should be used to provide the projected population within each area for (1) the expected first year of plant operation and (2) by census decade (e.g., 2000) through the projected plant life. The tables should provide population totals for each segment and annular ring, and a total for the 0 to 10 miles enclosed population. The basis for population projections should be described. The applicant should provide the methodology and sources used to obtain the population data, including the projections.

C.I.2.1.3.2 Population Between 10 and 50 Miles

A map of suitable scale and appropriately keyed tables should be used in the same manner as described above to describe the population and its distribution at 10-mile intervals between the 10- and 50-mile radii from the reactor.

C.I.2.1.3.3 Transient Population

Seasonal and daily variations in population and population distribution resulting from land uses such as recreational or industrial should be generally described and appropriately keyed to the areas and population numbers contained on the maps and tables of paragraphs 2.1.3.1 and 2.1.3.2. If the plant is located in an area where significant population variations due to transient land use are expected, additional tables of population distribution should be provided to indicate peak seasonal and daily populations. The additional tables should cover projected as well as current populations.

C.I.2.1.3.4 Low Population Zone

The low population zone (as defined in 10 CFR Part 100) should be specified and determined in accordance with the guideline provided in Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 2 (April 1998). A scaled map of the zone should be provided to illustrate topographic features; highways, railways, waterways, and any other transportation routes that may be used for evacuation purposes; and the location of all facilities and institutions such as schools, hospitals, prisons, beaches, and parks. Facilities and institutions beyond the low population zone which, because of their nature, may require special consideration when evaluating emergency plans, should be identified out to a distance of 5 miles. A table of population distribution within the low population zone should provide estimates of peak daily, as well as seasonal transient, population within the zone, including estimates of transient population in the facilities and institutions identified. The applicant should determine the LPZ so that appropriate protective measures could be taken in behalf of the enclosed populace in the event of an emergency.

C.I.2.1.3.5 Population Center

The nearest population center (as defined in 10 CFR Part 100) should be identified and its population and its direction and distance from the reactor specified. The distance from the reactor to the nearest boundary of the population center (not necessarily the political boundary) should be related to the low population zone radius to demonstrate compliance with guidelines provided in 10 CFR Part 100 and Regulatory Guide 4.7. The bases for the boundary selected should be provided. Indicate the extent to which transient population has been considered in establishing the population center. In addition to specifying the distance to the nearest boundary of a population center, discuss the present and projected population distribution and population density within and adjacent to local population groupings.

C.I.2.1.3.6 Population Density

DG-1145, Section C.I.2 - Site Characterization

The cumulative resident population projected for the year of initial plant operation should be plotted to a distance of at least 20 miles and compared with a cumulative population resulting from a uniform population density of 500 people/square mile in all directions from the plant. Similar information should be provided for the end of plant life but compared with a cumulative population resulting from a uniform population density of 1000 people/square mile. The applicant should demonstrate that the population density is in accordance with the guidelines provided in Regulatory guide 4.7.

C.I.2.2 Nearby Industrial, Transportation, and Military Facilities

The purpose of this section is to establish whether the effects of potential accidents in the vicinity² of the site from present and projected industrial, transportation, and military installations and operations should be used as design-basis events for plant design and to establish the design parameters related to the accidents so selected.

C.I.2.2.1 Locations and Routes

Provide maps showing the location and distance from the nuclear plant of all significant manufacturing plants; chemical plants; refineries; storage facilities; mining and quarrying operations; military bases; missile sites; transportation routes (air, land, and water); transportation facilities (docks, anchorages, airports); oil and gas pipelines, drilling operations, and wells; and underground gas storage facilities. Show any other facilities that, because of the products manufactured, stored, or transported, may require consideration with respect to possible adverse effects on the plant. Typically, adverse effects may be produced by toxic, flammable, and explosive substances. Examples include chlorine, ammonia, compressed or liquid hydrogen, liquid oxygen, and propane. Also, show any military firing or bombing ranges and any nearby aircraft flight, holding, and landing patterns.

The maps should be clearly legible and of suitable scale to enable easy location of the facilities and routes in relation to the nuclear plant. All symbols and notations used to depict the location of the facilities and routes should be identified in legends or tables. Topographic features should be included on the maps in sufficient detail to adequately illustrate the information presented.

C.I.2.2.2 Descriptions

The descriptions of the nearby industrial, transportation, and military facilities identified in Section C.I.2.2.1 should include the information indicated in the following sections.

C.I.2.2.2.1 Description of Facilities

²All facilities and activities within 5 miles of the nuclear plant should be considered. Facilities and activities at greater distances should be included as appropriate to their significance.

DG-1145, Section C.I.2 - Site Characterization

A concise description of each facility, including its primary function and major products and the number of persons employed, should be provided in tabular form.

C.I.2.2.2.2 Description of Products and Materials

A description of the products and materials regularly manufactured, stored, used, or transported in the vicinity of the nuclear plant or onsite should be provided. Emphasis should be placed on the identification and description of any hazardous materials. Statistical data should be provided on the amounts involved, modes of transportation, frequency of shipment, and the maximum quantity of hazardous material likely to be processed, stored, or transported at any given time. The applicable toxicity limits should be provided for each hazardous material.

C.I.2.2.2.3 Pipelines

For pipelines, indicate the pipe size, pipe age, operating pressure, depth of burial, location and type of isolation valves, and the type of gas or liquid presently carried. Indicate whether the pipeline is used for gas storage at higher than normal pressure and discuss the possibility of the pipeline being used in the future to carry a different product than the one presently being carried (e.g., propane instead of natural gas).

C.I.2.2.2.4 Waterways

If the site is located adjacent to a navigable waterway, provide information on the location of the intake structure(s) in relation to the shipping channel, the depth of channel, the location of locks, the type of ships and barges using the waterway, and any nearby docks and anchorages.

C.I.2.2.2.5 Highways

Nearby major highways or other roadways, as appropriate, should be described in terms of the frequency and quantities of hazardous substances that may be transported by truck in the vicinity of the plant site.

C.I.2.2.2.6 Railways.

Nearby railroads should be identified and information provided on the frequency and quantities of hazardous materials that may be transported in the vicinity of the plant site.

C.I.2.2.2.7 Airports

For airports, provide information on length and orientation of runways, type of aircraft using the facility, the number of operations per year by aircraft type, and the flying patterns associated with the airport. Plans for future utilization of the airport, including possible construction of new

DG-1145, Section C.I.2 - Site Characterization

runways, increased traffic, or utilization by larger aircraft, should be provided. In addition, statistics on aircraft accidents³ should be provided for:

- (1) All airports within 5 miles of the nuclear plant,
- (2) Airports with projected operations greater than 500d2 movements per year within 10 miles,⁴ and
- (3) Airports with projected operations greater than 1000d2 movements per year outside 10 miles.⁴

Provide equivalent information describing any other aircraft activities in the vicinity of the plant. These should include aviation routes, pilot training areas, and landing and approach paths to airports and military facilities.

C.I.2.2.2.8 Projections of Industrial Growth

For each of the above categories, provide projections of the growth of present activities and new types of activities in the vicinity of the nuclear plant that can be reasonably expected based on economic growth projections for the area.

C.I.2.2.3 Evaluation of Potential Accidents

On the basis of the information provided in Sections 2.2.1 and 2.2.2, the potential accidents to be considered as design-basis events should be determined and the potential effects of these accidents on the nuclear plant should be identified in terms of design parameter (e.g., overpressure, missile energies) or physical phenomena (e.g., concentration of flammable or toxic cloud outside building structures).

C.I.2.2.3.1 Determination of Design Basis Events

Design-basis events internal and external to the nuclear plant are defined as those accidents that have a probability of occurrence on the order of about 10^{-7} per year or greater and have potential consequences serious enough to affect the safety of the plant to the extent that Part 100 guidelines could be exceeded. The determination of the probability of occurrence of potential accidents should be based on an analysis of the available statistical data on the frequency of occurrence for the type of accident under consideration and on the transportation accident rates for the mode of transportation used to carry the hazardous material. If the probability of such an accident is on the order of 10^{-7} per year or greater, the accident should be considered a design-basis event, and a detailed analysis of the effects of the accident on the plant's safety-related structures and components should be provided. Because of the difficulty

³An analysis of the probability of an aircraft collision at the nuclear plant and the effects of the collision on the safety-related components of the plant should be provided in Section 3.5.

⁴ "d" is the distance in miles from the site.

DG-1145, Section C.I.2 - Site Characterization

of assigning accurate numerical values to the expected rate of low frequency hazards considered in this guide, judgement must be used as to the acceptability of the overall risk presented. Data for low probability events are often not available to permit accurate calculations. Accordingly, the expected rate of occurrence exceeding Part 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower. The accident categories discussed below should be considered in selecting design basis events.

- (1) Explosions. Accidents involving detonations of high explosives, munitions, chemicals, or liquid and gaseous fuels should be considered for facilities and activities in the vicinity of the plant or onsite where such materials are processed, stored, used, or transported in quantity. Attention should be given to potential accidental explosions that could produce a blast overpressure on the order of 1 psi or greater at the nuclear plant, using recognized quantity-distance relationships.⁵ Missiles generated in the explosion should also be considered, and an analysis should be provided in Section 3.5.
- (2) Flammable Vapor Clouds (Delayed Ignition). Accidental releases of flammable liquids or vapors that result in the formation of unconfined vapor clouds should be considered. Assuming that no immediate explosion occurs, the extent of the cloud and the concentrations of gas that could reach the plant under "worst-case" meteorological conditions should be determined. An evaluation of the effects on the plant of explosion and deflagration of the vapor cloud should be provided. An analysis of the missiles generated as a result of the explosion should be provided in Section 3.5.
- (3) Toxic Chemicals. Accidents involving the release of toxic chemicals (e.g., chlorine) from on site storage facilities and nearby mobile and stationary sources should be considered. If toxic chemicals are known or projected to be present on site or in the vicinity of a nuclear plant or to be frequently transported in the vicinity of the plant, releases of these chemicals should be evaluated. For each postulated event, a range of concentrations at the site should be determined for a spectrum of meteorological conditions. These toxic chemical concentrations should be used in evaluating control room habitability in Section 6.4.
- (4) Fires. Accidents leading to high heat fluxes or to smoke, and nonflammable gas- or chemical-bearing clouds from the release of materials as the consequence of fires in the vicinity of the plant should be considered. Fires in adjacent industrial and chemical plants and storage facilities and in oil and gas pipelines, brush and forest fires, and fires from transportation accidents should be evaluated as events that could lead to high heat fluxes or to the formation of such clouds. A spectrum of meteorological conditions should be included in the dispersal analysis when determining the concentrations of nonflammable material that could reach the site. These concentrations should be used

⁵One acceptable reference is the Department of the Army Technical Manual TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," for sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

DG-1145, Section C.I.2 - Site Characterization

in Section 6.4 to evaluate control room habitability and in Section 9.5 to evaluate the operability of diesels and other equipment.

- (5) Collisions with Intake Structure. For nuclear power plant sites located on navigable waterways, the evaluation should consider the probability and potential effects of impact on the plant cooling water intake structure and enclosed pumps by the various size, weight, and type of barges or ships that normally pass the site, including any explosions incident to the collision. This analysis should be used in Section 9.2.5 to determine whether an additional source of cooling water is required.
- (6) Liquid Spills. The accidental release of oil or liquids which may be corrosive, cryogenic, or coagulant should be considered to determine if the potential exists for such liquids to be drawn into the plant's intake structure and circulating water system or otherwise to affect the plant's safe operation.

C.I.2.2.3.2 Effects of Design Basis Events

Provide the analysis of the effects of the design basis accidents identified in Section C.I.2.2.3.1 on the safety-related components of the nuclear plant and discuss the steps taken to mitigate the consequences of these accidents, including such things as the addition of engineered-safety-feature equipment and reinforcing of plant structures, as well as the provisions made to lessen the likelihood and severity of the accidents themselves.

C.I.2.3 Meteorology

This section should provide a meteorological description of the site and its surrounding areas. Sufficient data should be included to permit an independent evaluation by the staff.

C.I.2.3.1 Regional Climatology

C.I.2.3.1.1 General Climate

The general climate of the region should be described with respect to types of air masses, synoptic features (high- and low-pressure systems and frontal systems), general airflow patterns (wind direction and speed), temperature and humidity, precipitation (rain, snow, and sleet), and relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions. Provide references that indicate the climatic atlases and regional climatic summaries used.

C.I.2.3.1.2 Regional Meteorological Conditions for Design and Operating Bases

Seasonal and annual frequencies of severe weather phenomena, including hurricanes, tornadoes and waterspouts, thunderstorms, lightning, hail, and high air pollution potential, should be provided. Provide the probable maximum annual frequency of occurrence and time duration of freezing rain (ice storms) and dust (sand) storms where applicable. Provide estimates of the weight of the 100-year return period snowpack and the weight of the 48-hour

DG-1145, Section C.I.2 - Site Characterization

probable maximum winter precipitation for the site vicinity for use in determining the weight of snow and ice on the roof of each safety-related structure.

Provide the meteorological data used for evaluating the performance of the ultimate heat sink with respect to (1) maximum evaporation and drift loss, (2) minimum water cooling, and (3) if applicable, the potential for water freezing in the ultimate heat sink water storage facility. (see Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants"). The period of record examined should be identified, and the bases and procedures used for selection of the critical meteorological data should be provided and justified.

Provide design-basis tornado parameters, including translational speed, rotational speed, maximum pressure differential with its associated time interval (see guidance in Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants"), and the 100-year return period 3-second gust wind speed.

Provide ambient temperature and humidity statistics (e.g., 0.4%, 2%, 99% and 99.6% annual exceedance dry-bulb temperatures; 0.4% annual exceedance wet-bulb temperature; 100-year return period maximum dry-bulb and wet-bulb temperatures; 100-year return period minimum dry-bulb temperature) for use in establishing heat loads for the design of plant heat sink systems and plant heating, ventilating, and air conditioning systems.

Provide the maximum rainfall rate.

Provide all other regional meteorological and air quality conditions used for design and operating basis considerations and their bases. References to FSAR sections in which these conditions are used should be included.

C.I.2.3.2 Local Meteorology

C.I.2.3.2.1 Normal and Extreme Values of Meteorological Parameters

Provide monthly and annual summaries (based on both long-term data from nearby reasonably representative locations and shorter-term onsite data) of:

- (1) Monthly and annual wind roses using the wind speed classes provided in Regulatory Guide 1.23, "Onsite Meteorological Programs," and wind direction persistence summaries at all heights at which wind characteristics data are applicable or have been measured.
- (2) Monthly and annual air temperature and dewpoint temperature summaries, including averages, measured extremes, and diurnal range.
- (3) Monthly and annual extremes of atmospheric water vapor (absolute and relative) including averages, measured extremes, and diurnal range.

DG-1145, Section C.I.2 - Site Characterization

- (4) Monthly and annual summaries of precipitation, including averages and measured extremes, number of hours with precipitation, rainfall rate distribution, (i.e., maximum 1 hr, 2 hr, ... 24 hr) and monthly precipitation wind roses with precipitation rate classes.
- (5) Monthly and annual summaries of fog (and smog), including expected values and extremes of frequency and duration.
- (6) Monthly and annual summaries of atmospheric stability defined by vertical temperature gradient or other well-documented parameters that have been substantiated by diffusion data.
- (7) Monthly mixing height data, including frequency and duration (persistence) of inversion conditions.
- (8) Hourly averages of wind speed and direction at all heights at which wind characteristics data are applicable or have been measured and hourly averages of atmospheric stability as defined by vertical temperature gradient or other well-documented parameters that have been substantiated by diffusion data. (These data should be presented as hour-by-hour data on electronic media and monthly and annual joint frequency distributions of wind speed and wind direction by atmospheric stability for all measurement levels.)

This information should be fully documented and substantiated as to the validity of its representation of conditions at and near the site. References should be provided to the National Weather Service (NOAA) station summaries from nearby locations and to other meteorological data that were used to describe site characteristics.

C.I.2.3.2.2 Potential Influence of the Plant and Its Facilities on Local Meteorology

Discuss and provide an evaluation of the potential modification of the normal and extreme values of meteorological parameters described in Section C.I.2.3.2.1 above as a result of the presence and operation of the plant (e.g., the influence of cooling towers or water impoundment features on meteorological conditions). Provide a map showing the detailed topographic features (as modified by the plant) within a 5-mile (3.1 km) radius of the plant. Also provide a smaller scale map showing topography within a 50-mile (80 km) radius of the plant as well as a plot of maximum elevation versus distance from the center of the plant in each of the sixteen 22½-degree compass point sectors (centered on true north, north-northeast, northeast, etc.) radiating from the plant to a distance of 50 miles (80 km).

C.I.2.3.2.3 Local Meteorological Conditions for Design and Operating Bases

Provide all local meteorological and air quality conditions used for design and operating basis considerations and their bases, except for those conditions referred to in Sections C.I.2.3.4 and 2.3.5. References should be included to FSAR sections in which these conditions are used.

C.I.2.3.3 Onsite Meteorological Measurements Program

The preoperational and operational programs for meteorological measurements at the site, including offsite satellite facilities, should be described. This description should include a site map showing tower location, measurements made, elevations of measurements, exposure of instruments, descriptions of instruments used, instrument performance specifications, calibration and maintenance procedures, data output and recording systems and locations, and data processing and analysis procedures. Additional sources of meteorological data for consideration in the description of airflow trajectories from the site to a distance of 80 km should be similarly described in as much detail as possible, particularly measurements made, locations and elevations of measurements, exposure of instruments, descriptions of instruments used, and instrument performance specifications. These additional sources of meteorological data may include National Weather Service stations and other meteorological programs that are well maintained and well exposed (e.g., other nuclear facilities, university and private meteorological programs). Guidance on acceptable onsite meteorological programs is presented in Regulatory Guide 1.23.

Provide joint frequency distributions of wind speed and direction by atmospheric stability class (derived from currently acceptable parameters), based on appropriate meteorological measurement heights and data reporting periods, in the format described in Regulatory Guide 1.23. An hour-by-hour listing of hourly-averaged parameters should also be provided on electronic media.

At least two consecutive annual cycles (and preferably three or more whole years), including the most recent 1-year period, should be provided at docketing.

Evidence should be provided to show how well these data represent long-term conditions at the site.

C.I.2.3.4 Short-Term (Accident Release) Atmospheric Dispersion Estimates

C.I.2.3.4.1 Objective

Provide for appropriate time periods up to 30 days after an accident (1) conservative and realistic estimates of atmospheric dispersion factors (χ/Q values) at the site boundary (exclusion area) and at the outer boundary of the low population zone, and (2) conservative X/Q values at the control room.

C.I.2.3.4.2 Calculations

Dispersion estimates should be based on the most representative meteorological data. Evidence should be provided to show how well these dispersion estimates represent conditions that would be estimated from anticipated long-term conditions at the site. The effects of topography on short-term dispersion estimates should be discussed.

- (1) Offsite Dispersion Estimates. Provide hourly cumulative frequency distributions of χ/Q values, using onsite data at appropriate distances from the effluent release point(s),

DG-1145, Section C.I.2 - Site Characterization

such as the minimum site boundary distance (exclusion area). The χ/Q values from each of these distributions that are exceeded 5 percent and 50 percent (median value) of the time should be reported. For the outer boundary of the low population zone, provide cumulative frequency of χ/Q estimates for (1) the 8-hour time period from 0 to 8 hours; (2) the 16-hour period from 8 to 24 hours; (3) the 3-day period from 1 to 4 days; and (4) the 26-day period from 4 to 30 days. Report the worst condition and the 5 percent and 50 percent probability level conditions. Guidance on appropriate diffusion models for estimating offsite χ/Q values is presented in Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants.

- (2) Control Room Dispersion Estimates. Provide control room χ/Q values that are not exceeded by more than 5% of the time for all potential accident release points for use in control room radiological habitability analyses. A site plan showing true North and indicating locations of all potential accident release pathways and control room intake and unfiltered inleakage pathways should be provided. Guidance on appropriate dispersion models for estimating control room χ/Q values is presented in Regulatory Guide 1.194, "Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants."

C.I.2.3.5 Long-Term (Routine Release) Atmospheric Dispersion Estimates

C.I.2.3.5.1 Objective

Provide realistic estimates of annual average atmospheric transport and diffusion characteristics to a distance of 50 miles (80 km) from the plant for annual average release limit calculations and man-rem estimates.

C.I.2.3.5.2 Calculations

Provide a detailed description of the model used to calculate realistic annual average χ/Q values. Discuss the accuracy and validity of the model, including the suitability of input parameters, source configuration, and topography. Provide the meteorological data summaries (onsite and regional) used as input to the models. Guidance on acceptable atmospheric transport and dispersion models is presented in Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors."

Provide a calculation of the maximum annual average χ/Q value at or beyond the site boundary utilizing appropriate meteorological data for each routine venting location. Estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 miles (80.5 km) from the plant using appropriate meteorological data should be provided.

Evidence should be provided to show how well these estimates represent conditions that would be estimated from climatologically representative data.

C.I.2.4 Hydrologic Engineering

DG-1145, Section C.I.2 - Site Characterization

Provide sufficient information to allow an independent hydrologic engineering review to be made of all hydrologically related design bases, performance requirements, and bases for operation of structures, systems, and components important to safety, considering the following phenomena or conditions:

- (1) probable maximum precipitation, onsite and on contributing drainage area
- (2) runoff floods for streams, reservoirs, adjacent drainage areas, and site drainage, and flood waves resulting from dam failures induced by runoff floods,
- (3) surges, seiches, and wave action,
- (4) tsunami,
- (5) nonrunoff-induced flood waves due to dam failures or landslides, and floods due to failure of on or near-site water control structures,
- (6) blockage of cooling water sources by natural events,
- (7) ice jam flooding,
- (8) combinations of flood types,
- (9) low water and/or drought effects (including setdown due to surges, seiches, frazil and anchor ice, or tsunami) on safety-related cooling water supplies and their dependability,
- (10) channel diversions of safety-related cooling water sources,
- (11) capacity requirements for safety-related cooling water sources, and
- (12) dilution and dispersion of severe accidental releases to the hydrosphere relating to existing and potential future users of surface water and groundwater resources.

The level of analysis that should be presented may range from very conservative, based on simplifying assumptions, to detailed analytical estimates of each facet of the bases being studied. The former approach is suggested in evaluating phenomena that do not influence the selection of design bases or where the adoption of very conservative design bases does not adversely affect plant design.

C.I.2.4.1 Hydrologic Description

C.I.2.4.1.1 Site and Facilities

Describe the site and all safety-related elevations, structures, exterior accesses, equipment, and systems from the standpoint of hydrologic considerations both surface and subsurface. Provide a topographic map of the site that shows any proposed changes to natural drainage features.

C.I.2.4.1.2 Hydrosphere

Describe the location, size, shape, and other hydrologic characteristics of streams, lakes, shore regions, and groundwater environments influencing plant siting. Include a description of existing and proposed water control structures, both upstream and downstream, that may influence conditions at the site. For these structures, (1) tabulate contributing drainage areas, (2) describe types of structures, all appurtenances, ownership, seismic design criteria, and spillway design criteria, and (3) provide elevation-area-storage relationships and short-term and long-term storage allocations for pertinent reservoirs. Provide a regional map showing major hydrologic features. List the owner, location, and rate of use of surface water users whose intakes could be adversely affected by accidental release of contaminants. Refer to Section 2.4.13.2 for the tabulation of groundwater users.

C.I.2.4.2 Floods

A “flood” is defined as any abnormally high water stage or overflow in a stream, floodway, lake, or coastal area that results in significantly detrimental effects.

C.I.2.4.2.1 Flood History

Provide the date, level, peak discharge, and related information for major historical flood events in the site region. Include stream floods, surges, seiches, tsunami, dam failures, ice jams, floods induced by landslides, and similar events.

C.I.2.4.2.2 Flood Design Considerations

Discuss the general capability of safety-related facilities, systems, and equipment to withstand floods and flood waves. Show how the design flood protection for safety-related components and structures of the plant is based on the highest calculated flood water level elevations and flood wave effects (design basis flood) resulting from analyses of several different hypothetical causes. Discuss how any possible flood condition up to and including the highest and most critical flood level resulting from any of several different events was considered as the basis for the design protection level for safety-related components and structures of the plant. Discuss the flood potential from streams, reservoirs, adjacent watersheds, and site drainage, including (1) the probable maximum water level from a stream flood, surge, seiche, combination of surge and stream flood in estuarial areas, wave action, or tsunami (whichever is applicable and/or greatest), and (2) the flood level resulting from the most severe flood wave at the plant site caused by an upstream or downstream landslide, dam failure, or dam breaching resulting from a hydrologic, seismic, or foundation disturbance. Discuss the effects of superimposing the coincident wind-generated wave action on the applicable flood level. Evaluate the assumed hypothetical conditions both statically and dynamically to determine the design flood protection level. Summarize the types of events considered and the controlling event or combination of events.

C.I.2.4.2.3 Effects of Local Intense Precipitation

Describe the effects of local probable maximum precipitation (see Section 2.4.3.1) on adjacent drainage areas and site drainage systems, including drainage from the roofs of structures. Tabulate rainfall intensities for the selected and critically arranged time increments, provide characteristics and descriptions of runoff models, and estimate the resulting water levels. Summarize the design criteria for site drainage facilities and provide analyses that demonstrate the capability of site drainage facilities to prevent flooding of safety-related facilities resulting from local probable maximum precipitation. Provide sufficient details of the site drainage system to allow (1) an independent review of rainfall and runoff effects on safety-related facilities, (2) a judgement concerning the adequacy of design criteria, and (3) an independent review of the potential for blockage of site drainage due to ice, debris, or similar material.

Provide a discussion of the effects of ice accumulation on site facilities where such accumulation could coincide with local probable maximum (winter) precipitation and cause flooding or other damage to safety-related facilities.

C.I.2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers

Describe how the hydrological design basis considers any potential hazard to the plant's safety-related facilities due to the effect of the PMF on streams and rivers. Summarize the locations and associated water levels for which PMF determinations have been made.

C.I.2.4.3.1 Probable Maximum Precipitation (PMP)

Discuss considerations of storm configuration (orientation of areal distribution), maximized precipitation amounts (include a description of maximization procedures and/or studies available for the area such as reference to National Weather Service and Corps of Engineers determinations), time distributions, orographic effects, storm centering, seasonal effects, antecedent storm sequences, antecedent snowpack (depth, moisture content, areal distribution), and any snowmelt model in defining the PMP. Present the selected maximized storm precipitation distribution (time and space).

C.I.2.4.3.2 Precipitation Losses

Describe the absorption capability of the basin, including consideration of initial losses, infiltration rates, and antecedent precipitation. Provide verification of these assumptions by reference to regional studies or by presenting detailed applicable local storm-runoff studies.

C.I.2.4.3.3 Runoff and Stream Course Models

Describe the hydrologic response characteristics of the watershed to precipitation (such as unit hydrographs), verification from historical floods or synthetic procedures, and methods adopted to account for nonlinear basin response at high rainfall rates. Provide a description of watershed subbasin drainage areas (including a map), their sizes, and topographic features. Include a tabulation of all drainage areas. Discuss the stream course model and its ability to compute floods up to the severity of the PMF. Present any reservoir and channel routing

DG-1145, Section C.I.2 - Site Characterization

assumptions and coefficients and their bases with appropriate discussion of initial conditions, outlet works (controlled and uncontrolled), and spillways (controlled and uncontrolled).

C.I.2.4.3.4 Probable Maximum Flood Flow

Present the controlling PMF runoff hydrograph at the plant site that would result from rainfall (and snowmelt if pertinent). Discuss how the analysis considered all appropriate positions and distributions of the PMP and the potential influence of existing and proposed upstream and downstream dams and river structures. Present analyses and conclusions concerning the ability of any upstream dams that may influence the site to withstand PMF conditions combined with setup, waves, and runup from appropriate coincident winds (see Section C.I.2.4.3.6). If failures are likely, show the flood hydrographs at the plant site resulting from the most critical combination of such dam failures, including domino-type failures of dams upstream of the plant site. When credit is taken for flood lowering at the plant site as a result of failure of any downstream dam during a PMF, support the conclusion that the downstream dam has a very high likelihood of failure. Finally, provide the estimated PMF discharge hydrograph at the site and, when available, provide a similar hydrograph without upstream reservoir effects to allow an evaluation of reservoir effects and a regional comparison of the PMF estimate to be made.

C.I.2.4.3.5 Water Level Determinations

Describe the translation of the estimated peak PMP discharge to elevation using (when applicable) cross-section and profile data, reconstitution of historical floods (with consideration of high water marks and discharge estimates), standard step methods, transient flow methods, roughness coefficients, bridge and other losses, verification, extrapolation of coefficients for the PMF, estimates of PMF water surface profiles, and flood outlines.

C.I.2.4.3.6 Coincident Wind Wave Activity

Discuss setup, significant (average height of the maximum 33-1/3% of all waves) and maximum (average height of the maximum 1% of all waves) wave heights, runup, and resultant static and dynamic effects of wave action on each safety-related facility from wind-generated activity that may occur coincidentally with the peak PMF water level. Provide a map and analysis showing that the most critical fetch has been used to determine wave action.

C.I.2.4.4 Potential Dam Failures, Seismically Induced

Describe how the hydrological design basis considers any potential hazard to the plant's safety-related facilities due to the seismically induced failure of upstream and downstream water control structures. Describe the worst combination failure (domino or simultaneous) that affects the site with respect to the maximum flood.

C.I.2.4.4.1 Dam Failure Permutations

Discuss the locations of dams (both upstream and downstream), potential modes of failure, and results of seismically induced dam failures that could cause the most critical conditions (floods or low water) with respect to the safety-related facilities for such an event (see Section

DG-1145, Section C.I.2 - Site Characterization

C.I.2.4.3.4). Discuss how consideration was given to possible landslides, pre-seismic-event reservoir levels, and antecedent flood flows coincident with the flood peak (base flow). Present the determination of the peak flow rate at the site for the worst dam failure reasonably possible or combination of dam failures, and summarize all analyses to show that the presented condition is the worst permutation. Include descriptions of all coefficients and methods used and their bases. Also discuss how consideration was given to the effects on plant safety of other potential concurrent events such as blockage of a stream, waterborne missiles, etc.

C.I.2.4.4.2 Unsteady Flow Analysis of Potential Dam Failures

In determining the effect of dam failures at the site (see Section C.I.2.4.4.1), describe how the analytical methods presented (1) are applicable to artificially large floods with appropriately acceptable coefficients and (2) consider flood waves through reservoirs downstream of failures. If applicable, discuss how domino-type failures resulting from flood waves were considered. Discuss estimates of coincident flow and other assumptions used to attenuate the dam-failure flood wave downstream. Discuss static and dynamic effects of the attenuated wave at the site.

C.I.2.4.4.3 Water Level at Plant Site

Describe the backwater, unsteady flow, or other computational method leading to the water elevation estimate (Section C.I.2.4.4.1) for the most critical upstream dam failure or failures, and discuss its verification and reliability. Superimpose wind and wave conditions that may occur simultaneously in a manner similar to that described in Section C.I.2.4.3.6.

C.I.2.4.5 Probable Maximum Surge and Seiche Flooding

C.I.2.4.5.1 Probable Maximum Winds and Associated Meteorological Parameters

Present the determination of probable maximum meteorological winds in detail. Describe the analysis of actual historical storm events in the general region and the modifications and extrapolations of data made to reflect a more severe meteorological wind system than actually recorded. Where this has been done previously or on a generic basis (e.g., Atlantic and Gulf Coast Probable Maximum Hurricane characteristics reported in NOAA Technical Report NWS 23, 1979), reference to that work with a brief description. Provide sufficient bases and information to ensure that the parameters presented are the most severe combination.

C.I.2.4.5.2 Surge and Seiche Water Levels

Provide historical data related to surges and seiches. Discuss considerations of hurricanes, frontal (cyclonic) type windstorms, moving squall lines, and surge mechanisms that are possible and applicable to the site. Include the antecedent water level (the 10% exceedance high tide, including initial rise for coastal locations, or the 100-year recurrence interval high water for lakes), the determination of the controlling storm surge or seiche (include the parameters used in the analysis such as storm track, wind fields, fetch or direction of wind approach, bottom effects, and verification of historic events), a detailed description of the methods and models used, and the results of the computation of the probable maximum surge hydrograph (graphical

DG-1145, Section C.I.2 - Site Characterization

presentation). Provide a detailed description of the (1) bottom profile and (2) shoreline protection and safety-related facilities.

C.I.2.4.5.3 Wave Action

Discuss the wind-generated wave activity that can occur coincidentally with a surge or seiche, or independently. Present estimates of the wave period and the significant (average height of the maximum 33-1/3% of all waves) and maximum (average height of the maximum 1% of all waves) wave heights and elevations with the coincident water level hydrograph. Present specific data on the largest breaking wave height, setup, runup, and the effect of overtopping in relation to each safety-related facility. Include a discussion of the effects of the water levels on each affected safety-related facility and the protection to be provided against hydrostatic forces and dynamic effects of splash.

C.I.2.4.5.4 Resonance

Discuss the possibility of oscillations of waves at natural periodicity, such as lake reflection and harbor resonance phenomena, and any resulting effects at the site.

C.I.2.4.5.5 Protective Structures

Discuss the location of and design criteria for any special facilities for the protection of intake, effluent, and other safety-related facilities against surges, seiches, and wave action.

C.I.2.4.6 Probable Maximum Tsunami Flooding

For sites that may be subject to tsunami or tsunami-like waves, discuss historical tsunami, either recorded or translated and inferred, that provide information for use in determining the probable maximum water levels and the geoseismic generating mechanisms available, with appropriate references to Section C.I.2.5.

C.I.2.4.6.1 Probable Maximum Tsunami

Present the determination of the probable maximum tsunami. Discuss consideration given to the most reasonably severe geoseismic activity possible (resulting from, for example, fractures, faults, landslides, volcanism) in determining the limiting tsunami-producing mechanism. Summarize the geoseismic investigations used to identify potential tsunami sources and mechanisms and the resulting locations and mechanisms that could produce the controlling maximum tsunami at the site (from both local and distant generating mechanisms). Discuss how the orientation of the site relative to the earthquake epicenter or generating mechanism, shape of the coastline, offshore land areas, hydrography, and stability of the coastal area (proneness of sliding) were considered in the analysis. Also discuss hillslope failure-generated tsunami-like waves on inland sites. Discuss the potential of an earthquake-induced tsunami on a large body of water, if relevant for the site.

C.I.2.4.6.2 Historical Tsunami Record

DG-1145, Section C.I.2 - Site Characterization

Provide local and regional historical tsunami information, including any relevant paleo-tsunami evidence.

C.I.2.4.6.3 Source Generator Characteristics

Provide detailed geoseismic descriptions of the controlling local and distant tsunami generators, including location, source dimensions, fault orientation (if applicable), and maximum displacement.

C.I.2.4.6.4 Tsunami Analysis

Provide a complete description of the analysis procedure used to calculate tsunami wave height and period at the site. Describe all models used in the analysis in detail, including the theoretical bases of the models, their verification, and the conservatism of all input parameters.

C.I.2.4.6.5 Tsunami Water Levels

Provide estimates of maximum and minimum (low water) tsunami wave heights from both distant and local generators. Describe the ambient water levels, including tides, sea level anomalies, and wind waves assumed coincident with the tsunami.

C.I.2.4.6.6 Hydrography and Harbor or Breakwater Influences on Tsunami

Present the routing of the controlling tsunami, including breaking wave formation, bore formation, and any resonance effects (natural frequencies and successive wave effects) that result in the estimate of the maximum tsunami runup on each pertinent safety-related facility. Include a discussion both of the analysis used to translate tsunami waves from offshore generator locations, or in deep water, to the site and of antecedent conditions. Provide, where possible, verification of the techniques and coefficients used by reconstituting tsunami of record.

C.I.2.4.6.7 Effects on Safety-Related Facilities

Discuss the effects of the controlling tsunami on safety-related facilities and discuss the design criteria for the tsunami protection and mitigation to be provided.

C.I.2.4.7 Ice Effects

Describe potential icing effects and design criteria for protecting safety-related facilities from the most severe ice sheets, ice jam flood, wind-driven ice ridges, or other ice-produced effects and forces that are reasonably possible and could affect safety-related facilities with respect to adjacent streams, lakes, etc., for both high and low water levels. Include the location and proximity of such facilities to the ice-generating mechanisms. Describe the regional ice and ice jam formation history with respect to water bodies. Describe the potential for formation of frazil and anchor ice at the site. Discuss the effects of ice-induced reduction in capacity of water storage facilities as they affect safety-related SSCs.

C.I.2.4.8 Cooling Water Canals and Reservoirs

Present the design bases for the capacity and the operating plan for safety-related cooling water canals and reservoirs (reference Section C.I.2.4.11). Discuss and provide bases for protecting the canals and reservoirs against wind waves, flow velocities (including allowance for freeboard), and blockage and (where applicable) describe the ability to withstand a probable maximum flood, surge, etc.

Discuss the emergency storage evacuation of reservoirs (low-level outlet and emergency spillway). Describe verified runoff models (e.g., unit hydrographs), flood routing, spillway design, and outlet protection.

C.I.2.4.9 Channel Diversions

Discuss the potential for upstream diversion or rerouting of the source of cooling water (resulting from, for example, channel migration, river cutoffs, ice jams, or subsidence) with respect to seismic, topographical, geologic, and thermal evidence in the region. Present the history of flow diversions and realignments in the region. Discuss the potential for adversely affecting safety-related facilities or water supply, and describe available alternative safety-related cooling water sources in the event that diversions are possible.

C.I.2.4.10 Flooding Protection Requirements

Describe the static and dynamic consequences of all types of flooding on each pertinent safety-related facility. Present the design bases required to ensure that safety-related facilities will be capable of surviving all design flood conditions, and reference appropriate discussions in other sections of the FSAR where the design bases are implemented. Describe various types of flood protection used and the emergency procedures to be implemented (where applicable).

C.I.2.4.11 Low Water Considerations

C.I.2.4.11.1 Low Flow in Rivers and Streams

Estimate and provide the design basis for the flow rate and water level resulting from the most severe drought considered reasonably possible in the region, if such conditions could affect the ability of safety-related facilities, particularly the ultimate heat sink, to perform adequately. Include considerations of downstream dam failures (see Section C.I.2.4.4). For non-safety related water supplies, demonstrate that the supply will be adequate during a 100-year drought.

C.I.2.4.11.2 Low Water Resulting from Surges, Seiches, or Tsunami

Determine the surge-, seiche-, or tsunami-caused low water level that could occur from probable maximum meteorological or geoseismic events, if such level could affect the ability of safety-related features to function adequately. Include a description of the probable maximum meteorological event (its track, associated parameters, antecedent conditions) and the computed low water level, or a description of the applicable tsunami conditions. Also consider,

DG-1145, Section C.I.2 - Site Characterization

where applicable, ice formation or ice jams causing low flow since such conditions may affect the safety-related cooling water source.

C.I.2.4.11.3 Historical Low Water

If statistical methods are used to extrapolate flows and/or levels to probable minimum conditions, discuss historical low water flows and levels and their probabilities (unadjusted for historical controls and adjusted for both historical and future controls and uses).

C.I.2.4.11.4 Future Controls

Provide the estimated flow rate, durations, and levels for drought conditions considering future uses, if such conditions could affect the ability of safety-related facilities to function adequately. Substantiate any provisions for flow augmentation for plant use.

C.I.2.4.11.5 Plant Requirements

Present the required minimum safety-related cooling water flow, the sump invert elevation and configuration, the minimum design operating level, pump submergence elevations (operating heads), and design bases for effluent submergence, mixing, and dispersion. Discuss the capability of cooling water pumps to supply sufficient water during periods of low water resulting from the 100-year drought. Refer to Sections 9.2.1, 9.2.5, and 10.4.5 where applicable. Identify or refer to institutional restraints on water use.

C.I.2.4.11.6 Heat Sink Dependability Requirements

Identify all sources of normal and emergency shutdown water supply and related retaining and conveyance systems.

Identify design bases used to compare minimum flow and level estimates with plant requirements and describe any available low water safety factors (see Sections C.I.2.4.4 and C.I.2.4.11). Describe (or refer to Section 9.2.5) the design bases for operation and normal or accidental shutdown and cooldown during (1) the most severe natural and site-related accident phenomena, (2) reasonable combinations of less severe phenomena, and (3) single failures of man-made structural components. Describe the design for protecting all structures related to the ultimate heat sink during the above events. Identify the sources of water and related retaining and conveyance systems that will be designed for each of the above bases or situations.

Describe the ability to provide sufficient warning of impending low flow or low water levels to allow switching to alternative sources where necessary. Identify conservative estimates of heat dissipation capacity and water losses (such as drift, seepage, and evaporation). Indicate whether, and if so how, guidance given in Regulatory Guide (RG) 1.27, "Ultimate Heat Sink for Nuclear Power Plants," has been followed; if not followed, describe the specific alternative approaches used.

DG-1145, Section C.I.2 - Site Characterization

Identify or refer to descriptions of any other uses of water drawn from the ultimate heat sink, such as fire water or system charging requirements. If interdependent water supply systems are used, such as an excavated reservoir within a cooling lake or tandem reservoirs, describe the ability of the principal portion of the system to survive the failure of the secondary portion. Provide the bases for and describe the measures to be taken (dredging or other maintenance) to prevent loss of reservoir capacity as a result of sedimentation.

C.I.2.4.12 Groundwater

Present all groundwater data or cross-reference the groundwater data presented in Section C.I.2.5.4.

C.I.2.4.12.1 Description and Onsite Use

Describe the regional and local groundwater aquifers, formations, sources, and sinks. Describe the type of groundwater use, wells, pumps, storage facilities, and flow requirements of the plant. If groundwater is to be used as a safety-related source of water, compare the design basis protection from natural and accident phenomena with RG 1.27 criteria. Indicate whether, and if so how, the RG 1.27 guidelines have been followed; if RG 1.27 guidelines were not followed, describe the specific alternative approaches used, including the bases and sources of data.

C.I.2.4.12.2 Sources

Describe present and projected future regional water use. Tabulate existing users (amounts, water levels and elevations, locations, and drawdown). Tabulate or illustrate the history of groundwater or piezometric level fluctuations beneath and in the vicinity of the site. Provide groundwater or piezometric contour maps of aquifers beneath and in the vicinity of the site to indicate flow directions and gradients. Discuss the seasonal and long-term variations of these aquifers. Indicate the range of values and the method of determination for vertical and horizontal permeability and total and effective porosity (specific yield) for each relevant geologic formation beneath the site. Discuss the potential for reversibility of groundwater flow resulting from local areas of pumping for both plant and nonplant use. Describe the effects of present and projected groundwater use (wells) on gradients and groundwater or piezometric levels beneath the site. Note any potential groundwater recharge area such as lakes or outcrops within the influence of the plant.

C.I.2.4.12.3 Subsurface Pathways

Provide a conservative analysis of all groundwater pathways of a liquid effluent release at the site. Evaluate (where applicable) the dispersion, ion-exchange, and dilution capability of the groundwater environment with respect to present and projected users. Identify potential pathways of contamination to nearby groundwater users and to springs, lakes, streams, etc. Determine groundwater and radionuclide (if necessary) travel time to the nearest downgradient groundwater user or surface body of water. Include all methods of calculation, data sources, models, and parameters or coefficients used such as dispersion coefficients, dispersivity,

DG-1145, Section C.I.2 - Site Characterization

distribution (adsorption) coefficients, hydraulic gradients, and values of permeability, total and effective porosity, and bulk density along contaminant pathways.

C.I.2.4.12.4 Monitoring or Safeguard Requirements

Present and discuss plans, procedures, safeguards, and monitoring programs to be used to protect present and projected groundwater users.

C.I.2.4.12.5 Design Bases for Subsurface Hydrostatic Loading

- (1) For plants not employing permanent dewatering systems, describe the design bases for groundwater-induced hydrostatic loadings on subsurface portions of safety-related structures, systems, and components. Discuss the development of these design bases. Where dewatering during construction is critical to the integrity of safety-related structures, describe the bases for subsurface hydrostatic loadings assumed during construction and the dewatering methods to be employed in achieving these loadings.

Where wells are proposed for safety-related purposes, discuss the hydrodynamic design bases for protection against seismically-induced pressure waves.

- (2) For plants employing permanent dewatering systems:
- (a) Provide a description of the proposed dewatering system, including drawings showing the proposed locations of affected structures, components, and features of the system. Provide information related to the hydrologic design of all system components. Where the dewatering system is important to safety, provide a discussion of its expected functional reliability, including comparisons of proposed systems and components with the performance of existing and comparable systems and components for applications under site conditions similar to those proposed.
 - (b) Provide estimates and their bases for soil and rock permeabilities, total porosity, effective porosity (specific yield), storage coefficient, and other related parameters used in the design of the dewatering system. If available, provide the results of monitoring pumping rates and flow patterns during dewatering for the construction excavation.
 - (c) Provide analyses and their bases for estimates of groundwater flow rates in the various parts of the permanent dewatering system, the area of influence of drawdown, and the shapes of phreatic surfaces to be expected during operation of the system.
 - (d) Provide analyses, including their bases, to establish conservative estimates of the time available to mitigate the consequences of the system degradation that

DG-1145, Section C.I.2 - Site Characterization

could cause groundwater levels to exceed design bases. Document the measures that will be taken to repair the system or to provide an alternative dewatering system that would become operational before the design-basis groundwater level is exceeded.

- (e) Provide both the design basis and normal operation groundwater levels for safety-related structures, systems, and components. Describe how the design basis groundwater level reflects abnormal and rare events (such as an occurrence of the safe shutdown earthquake (SSE), a failure of a circulating water system pipe, or a single failure within the system) that can cause failure or overloading of the permanent dewatering system.
- (f) Postulate a single failure of a critical active feature or component during any design basis event. Unless it can be documented that the potential consequences of the failure will not result in dose guidelines exceeding those in RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste Containing Components of Nuclear Power Plants," and RG 1.29, "Seismic Design Classification," either (1) document by pertinent analyses that groundwater level recovery times are sufficient to allow other forms of dewatering to be implemented before the design-basis groundwater level is exceeded, discuss the measures to be implemented and equipment needed, and identify the amount of time required to accomplish each measure, or (2) show how all system components are design for all severe phenomena and events.
- (g) Where appropriate, document the bases that ensure the ability of the system to withstand various natural and accidental phenomena such as earthquakes, tornadoes, surges, floods, and a single failure of a component feature of the system (such as a failure of any cooling water pipe penetrating, or in close proximity to, the outside walls of safety-related buildings where the groundwater level is controlled by the system). Provide an analysis of the consequences of pipe ruptures on the proposed underdrain system, including consideration of postulated breaks in the circulating system pipes at, in, or near the dewatering system building either independently of, or as a result of the SSE.
- (h) State the maximum groundwater level the plant structures can tolerate under various significant loading conditions in the absence of the underdrain system.
- (i) Provide a description of the proposed groundwater level monitoring programs for dewatering during plant construction and for permanent dewatering during plant operation. Provide (1) the general arrangement in plans and profile with approximate elevation of piezometers and observation wells to be installed, (2) intended zone(s) of placement, (3) type(s) of piezometer (closed or open system), (4) screens and filter gradation descriptions, (5) drawings showing typical installations showing limits of filter and seals, (6) observation schedules (initial and time intervals for subsequent readings), (7) plans for evaluation of recorded data, and (8) plans for alarm devices to ensure sufficient time for initiation of corrective action. Describe the implementation program, including

DG-1145, Section C.I.2 - Site Characterization

milestones, for the construction and operational groundwater level monitoring programs for dewatering.

- (j) Provide information regarding the outlet flow monitoring program. The information required includes (1) the general location and type of flow measurement device(s) and (2) the observation plan and alarm procedure to identify unanticipated high or low flow in the system and the condition of the effluent. Describe the implementation program, including milestones, for the outlet flow monitoring program.
- (k) Describe how information gathered during dewatering for construction excavation will be used to implement or substantiate assumed design bases.
- (l) Provide a technical specification for periods when the dewatering system may be exposed to sources of water not considered in the design. An example of such a situation would be the excavation of surface seal material for repair of piping such that the underdrain would be exposed to direct surface runoff. In addition, where the permanent dewatering system is safety related, is not completely redundant, or is not designed for all design-basis events, provide the bases for a technical specification with action levels, the remedial work required and the estimated time that it will take to accomplish the work, and the sources, types of equipment, and manpower required as well as the availability of the above under potentially adverse conditions.
- (m) Where wells are proposed for safety-related purposes, discuss the hydrodynamic design bases for protection against seismically-induced pressure waves.

C.I.2.4.13 Pathways of Liquid Effluents in Ground and Surface Waters

Describe the ability of the ground and surface water environment to delay, disperse, dilute, or concentrate liquid effluents as related to existing or potential future water users. Discuss the bases used to determine dilution factors, dispersion coefficients, flow velocities, travel times, adsorption and pathways of liquid contaminants. Refer to the locations and users of surface waters listed in Section C.I.2.4.1.2 and the release points identified in Section C.I.11.2.3.

C.I.2.4.14 Technical Specification and Emergency Operation Requirements

Describe any emergency protective measures designed to minimize the impact of adverse hydrology-related events on safety-related facilities. Describe the manner in which these requirements will be incorporated into appropriate technical specifications and emergency procedures. Discuss the need for any technical specifications for plant shutdown to minimize the consequences of an accident resulting from hydrologic phenomena such as floods or the degradation of the ultimate heat sink. In the event emergency procedures are to be used to meet safety requirements associated with hydrologic events, identify the event, present appropriate water levels and lead times available, indicate what type of action would be taken, and discuss the time required to implement each procedure.

C.I.2.5 Geology, Seismology, and Geotechnical Engineering

Provide information regarding the seismic and geologic characteristics of the site and the region surrounding the site to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the Safe Shutdown Earthquake Ground Motion (SSE), and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. Provide a summary that contains a synopsis of Sections C.I.2.5.1 through C.I.2.5.5, including a brief description of the site, the investigations performed, results of investigations, conclusions, and a statement as to who did the work.

C.I.2.5.1 Basic Geologic and Seismic Information

Basic geologic and seismic information is required throughout the following sections to provide a basis for evaluation. In some cases, this information applies to more than one section. The information may be presented under this section, under the following sections, or as appendices to this section, provided adequate cross-references are made in the appropriate sections.

Reference information obtained from published reports, maps, private communications, or other sources. Document information from surveys, geophysical investigations, borings, trenches, or other investigations by providing descriptions of techniques, graphic logs, photographs, laboratory results, identification of principal investigators, and other data necessary to assess the adequacy of the information.

C.I.2.5.1.1 Regional Geology

Discuss all geologic, seismic, tectonic, nontectonic, and manmade hazards within the site region. Provide a review of the regional tectonics, with emphasis on the Quaternary period, structural geology, seismology, paleoseismology, physiography, geomorphology, stratigraphy, and geologic history within a distance of 320 km (200 mi) from the site (site region). Discuss, document (by appropriate references), and illustrate such hazards as subsidence, cavernous or karst terrain, irregular weathering conditions, and landslide potential by presenting such items as a regional physiographic map, surface and subsurface geologic maps, isopach maps, regional gravity and magnetic maps, stratigraphic sections, tectonic and structure maps, fault maps, a site topographic map, a map showing areas of mineral and hydrocarbon extraction, boring logs, and aerial photographs. Include maps showing superimposed plot plans of the plant facilities.

Discuss the relationship between the regional and the site physiography. Include a regional physiographic map showing the site location. Identify and describe tectonic structures such as folds, faults, basins, and domes underlying the region surrounding the site, and include a discussion of their geologic history. Include a regional tectonic map showing the site location. Provide detailed discussions of the regional tectonic structures of significance to the site. Include detailed analyses of faults to determine their capacity for generating ground motions at the site and to determine the potential for surface faulting in Sections C.I.2.5.2 and C.I.2.5.3, respectively.

DG-1145, Section C.I.2 - Site Characterization

Describe the lithologic, stratigraphic, and structural geologic conditions of the region surrounding the site and their relationship to the site region's geologic history. Provide geologic profiles showing the relationship of the regional and local geology to the site location. Indicate the geologic province within which the site is located and the relation to other geologic provinces. Include regional geologic maps indicating the site location and showing both surface and bedrock geology.

C.I.2.5.1.2 Site Geology

Provide a description of the site-related geologic features, seismic conditions, and conditions caused by human activities, at appropriate levels of detail within areas approximately defined by radii of 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) around the site. Material on site geology included in this section may be cross-referenced in Section C.I.2.5.4.

Describe the site physiography and local land forms and discuss the relationship between the regional and site physiography. Include a site topographic map showing the locations of the principal plant facilities. Describe the configuration of the land forms and relate the history of geologic changes that have occurred. Evaluate areas that are significant to the site of actual or potential landsliding, surface or subsurface subsidence, uplift, or collapse resulting from natural features such as tectonic depression and cavernous or karst terrains.

Describe significant historical earthquakes as well as evidence (or lack of evidence) of paleoseismology. Also describe the local seismicity, including historical and instrumentally recorded earthquakes.

Describe the detailed lithologic and stratigraphic conditions of the site and the relationship to the regional stratigraphy. Describe the thicknesses, physical characteristics, origin, and degree of consolidation of each lithologic unit, including a local stratigraphic column. Furnish summary logs or borings and excavations such as trenches used in the geologic evaluation. Boring logs included in Section C.I.2.5.4 may be referenced.

Provide a detailed discussion of the structural geology in the vicinity of the site. Include in the discussion the relationship of site structure to regional tectonics, with particular attention to specific structural units of significance to the site such as folds, faults, synclines, anticlines, domes, and basins. Provide a large-scale structural geology map (1:24,000) of the site showing bedrock surface contours and including the locations of Seismic Category I structures. Furnish a large-scale geologic map (1:24,000) of the region within 8 km (5 mi) of the site that shows surface geology and that includes the locations of major structures of the nuclear power plant, including all Seismic Category I structures.

Distinguish areas of bedrock outcrop from which geologic interpretation has been extrapolated for areas in which bedrock is not exposed at the surface. When the interpretation differs substantially from the published geologic literature on the area, note and document the differences for the new conclusions presented. Discuss the geologic history of the site and relate it to the regional geologic history.

DG-1145, Section C.I.2 - Site Characterization

Include an evaluation from an engineering-geology standpoint of the local geologic features that affect the plant structures. Describe in detail the geologic conditions underlying all Seismic Category I structures, dams, dikes, and pipelines. Describe the dynamic behavior of the site during prior earthquakes. Identify deformational zones such as shears, joints, fractures, and folds, or combinations of these features and evaluate these zones relative to structural foundations. Describe and evaluate zones of alteration or irregular weathering profiles, zones of structural weakness, unrelieved residual stresses in bedrock, and all rocks or soils that might be unstable because of their mineralogy or unstable physical or chemical properties. Evaluate the effects of man's activities in the area such as withdrawal or addition of subsurface fluids or mineral extraction at the site.

Describe site groundwater conditions. Information included in Section 2.4.13 may be referenced in this section.

C.I.2.5.2 Vibratory Ground Motion

Present the criteria and describe the methodology used to establish the Safe Shutdown Earthquake (SSE) ground motion and the controlling earthquakes for the site.

C.I.2.5.2.1 Seismicity

Provide a complete list of all historically reported earthquakes that could have reasonably affected the region surrounding the site, including all earthquakes of Modified Mercalli Intensity (MMI) greater than or equal to IV or magnitude greater than or equal to 3.0 that have been reported within 320 km (200 mi) of the site. Also report large earthquakes outside of this area that would impact the SSE. Present a regional-scale map showing all listed earthquake epicenters, supplemented by a larger-scale map showing earthquake epicenters within 80 km (50 mi) of the site. Provide the following information concerning each earthquake whenever it is available: epicenter coordinates, depth of focus, date, origin time, highest intensity, magnitude, seismic moment, source mechanism, source dimensions, distance from the site, and any strong-motion recordings. Identify sources from which the information was obtained. Identify all magnitude designations such as m_b , M_L , M_s , or M_w . In addition, completely describe any earthquake-induced geologic failure, such as liquefaction (including paleoseismic evidence of large prehistoric earthquakes), landsliding, landspeading, and lurching, including the estimated level of strong motion that induced failure and the physical properties of the materials.

C.I.2.5.2.2 Geologic and Tectonic Characteristics of Site and Region

Identify each seismic source, any part of which is within 320 km (200 mi) of the site. For each seismic source, describe the characteristics of the geologic structure, tectonic history, present and past stress regimes, seismicity, recurrence, and maximum magnitudes that distinguish the various seismic sources and the particular areas within those sources where historical earthquakes have occurred. Discuss any alternative regional tectonic models derived from the literature. Augment the discussion in this section by a regional-scale map showing the seismic sources, earthquake epicenters, locations of geologic structures, and other features that characterize the seismic sources. In addition, provide a table of seismic sources that contains maximum magnitudes, recurrence parameters, a range of source-to-site distances, alternative

DG-1145, Section C.I.2 - Site Characterization

source models (including probability weighting factors), and any notable historical earthquakes or paleoseismic evidence of large prehistoric earthquakes.

C.I.2.5.2.3 Correlation of Earthquake Activity with Seismic Sources

Provide a correlation or association between the earthquakes discussed in Subsection C.I.2.5.2.1 and the seismic sources identified in Subsection C.I.2.5.2.2. Whenever an earthquake hypocenter or concentration of earthquake hypocenters can be reasonably correlated with geologic structures, provide the rationale for the association considering the characteristics of the geologic structure (including geologic and geophysical data, seismicity, and the tectonic history) and regional tectonic model. Include a discussion of the method used to locate the earthquake hypocenters, an estimation of their accuracy, and a detailed account that compares and contrasts the geologic structure involved in the earthquake activity with other areas within the seismotectonic province.

C.I.2.5.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquake

Provide a description of the probabilistic seismic hazard analysis (PSHA), including the underlying assumptions and methodology and how they follow or differ from the guidance provided in NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts." Describe how the results of the site investigations were used to update the seismic source characterizations in the PSHA or develop additional seismic sources. Provide the rationale for any minimum magnitude or other ground motion parameters (such as cumulative absolute velocity) used in the PSHA. Provide a description of the ground motion attenuation models used in the PSHA, including the rationale for including each model, consideration of uncertainty, model weighting, magnitude conversion, distance measure adjustments, and the model parameters for each spectral frequency. Describe and show how logic trees for seismic source parameters (maximum magnitude, recurrence, source geometry) and attenuation models were used for incorporation of model uncertainty.

Provide 15th, median, mean, and 85th fractile PSHA hazard curves for 0.5, 1, 2.5, 5, 7.5, 10, 25 and 100 (PGA) Hz frequencies both before and after correcting for local site amplification. Show and explain the relative contributions of each of the main seismic sources to the median and mean hazard curves. Also show and explain the effects of other significant modeling assumptions (source or ground motion attenuation) on the mean and median hazard curves. In addition, provide both the 10⁻⁴ and 10⁻⁵ mean and median uniform hazard response spectra (UHRS) derived from the PSHA hazard curves.

If the performance-based approach, described in American Society of Civil Engineers (ASCE) Standard 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," for seismic design bases (SDB) category 5D, is used, provide the controlling earthquake magnitudes and distances for the mean 10⁻⁴, 10⁻⁵, and 10⁻⁶ hazard levels at spectral frequencies of 1 and 2.5 Hz (low frequency) and 5 and 10 Hz (high frequency). If the reference probability approach, described in Regulatory Guide (RG) 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," is used, provide the controlling earthquake magnitudes and distances for the reference

DG-1145, Section C.I.2 - Site Characterization

probability hazard level at spectral frequencies of 1 and 2.5 Hz and 5 and 10 Hz. Describe the methodology used and how it either follows or differs from the procedure outlined in Appendix C of RG 1.165. Provide bar graph plots of both the low-frequency and high-frequency deaggregation results for each of the hazard levels. Provide a table showing each of the low- and high frequency controlling earthquakes.

Compare the controlling earthquake magnitudes and distances for the site with the controlling earthquakes and ground motions used in licensing (1) other licensed facilities at the site, (2) nearby plants, or (3) plants licensed in similar seismogenic regions. In addition, compare the controlling earthquakes to the historical earthquake record, any prehistoric earthquakes based on paleoseismic evidence, and the earthquake potential associated with each seismic source.

C.I.2.5.2.5 Seismic Wave Transmission Characteristics of the Site

Describe the site response analyses, including the method used to represent the uncertainty and variability across the site. Present the following material properties for each stratum under the site: thickness, seismic compressional and shear velocities, bulk densities, soil index properties and classification, shear modulus and damping variations with strain level, and the water table elevation and its variations. Describe the methods used to determine these properties, including the variability in each of these properties and the methods used to model the variability. Provide the shear modulus and damping relationships, including a comparison between the test results performed on site borings and the modulus and damping curves. Describe the site material properties to the depth that corresponds with the hard rock conditions assumed by the ground motion attenuation models used in the PSHA. In addition, provide the rationale for any assumed nonlinear rock behavior.

Provide the response spectra for each of the controlling earthquakes after scaling the spectra to the appropriate low or high frequency spectral acceleration value. Describe the method used, if necessary, to extend the response spectra beyond the range of frequencies defined for the ground motion attenuation models. Provide a description of the method used to develop the time histories for the site response analysis, including the time history database. Provide figures showing the initial time histories and final time histories, for which the response spectra have been scaled to the target earthquake response spectra.

Provide a description of the method used to compute the site amplification function for each controlling earthquake. Describe the computer program used to compute the site amplification functions. In addition, provide a figure showing the final site transfer function and a table of the results for frequencies ranging from 0.1 to 100 Hz.

C.I.2.5.2.6 Safe Shutdown Earthquake Ground Motion

Describe the methodology used to determine both the horizontal and vertical SSE ground motion. If the performance-based approach, described in ASCE Standard 43-05 for SDB category 5D, is used, provide a table with the mean 10^{-4} , 10^{-5} UHRS values, design factors, and horizontal SSE. If the reference-probability approach, described in RG 1.165, is used provide figures showing how the horizontal SSE envelopes the low- and high-frequency controlling

DG-1145, Section C.I.2 - Site Characterization

earthquake response spectra. Provide the vertical to horizontal (V/H) response spectral ratios used to determine the vertical SSE from the horizontal SSE.

Provide plots of both the horizontal and vertical SSE. In addition, provide a table with the horizontal SSE, V/H ratios, and vertical SSE.

C.I.2.5.3 Surface Faulting

Provide information describing whether or not a potential for surface deformation exists that could affect the site. Describe the detailed surface and subsurface geological, seismological, and geophysical investigations performed around the site to compile this information.

C.I.2.5.3.1 Geologic, Seismological, and Geophysical Investigations

Provide a description of the Quaternary tectonics, structural geology, stratigraphy, geochronological methods used, paleoseismology, and geological history for the site. Describe the lithologic, stratigraphic, and structural geologic conditions of the site and the area surrounding the site, including its geologic history. Include site and regional maps and profiles constructed at scales adequate to illustrate clearly the surficial and bedrock geology, structural geology, topography, and the relationship of the safety-related foundations of the nuclear power plant to these features.

C.I.2.5.3.2 Geological Evidence, or Absence of Evidence, for Surface Deformation

Provide sufficient surface and subsurface information, supported by detailed investigations, either to confirm the absence of surface tectonic deformation (i.e., faulting) or, if present, to demonstrate the age of its most recent displacement and ages of previous displacements. If tectonic deformation is present in the site vicinity, define the geometry, amount and sense of displacement, recurrence rate, and age of latest movement. In addition to geologic evidence that may indicate faulting, document linear features interpreted from topographic maps, low and high altitude aerial photographs, satellite imagery, and other imagery.

C.I.2.5.3.3 Correlation of Earthquakes with Capable Tectonic Sources

Provide an evaluation of all historically reported earthquakes within 40 km (25 mi) of the site with respect to hypocenter accuracy and source origin. Provide an evaluation of the potential for causing surface deformation for all capable tectonic sources that could, based on their orientations, extend to within 8 km (5 mi) of the site. Provide a plot of earthquake epicenters superimposed on a map showing the local capable tectonic structures.

C.I.2.5.3.4 Ages of Most Recent Deformations

Present the results of the investigation of identified faults or folds associated with blind faults, any part of which is within 8 km (5 mi) of the site. Provide estimates of the age of the most recent movement and identify geological evidence for previous displacements, if it exists. Describe the geological and geophysical techniques used and provide an evaluation of the sensitivity and resolution of the exploratory techniques used for each investigation.

C.I.2.5.3.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

Discuss the structure and genetic relationship between site area faulting or other tectonic deformation and the regional tectonic framework. In regions of active tectonics, discuss any detailed geologic and geophysical investigations conducted to demonstrate the structural relationships of site area faults with regional faults known to be seismically active.

C.I.2.5.3.6 Characterization of Capable Tectonic Sources

For all potential capable tectonic sources such as faults, or folds associated with blind faults, within 8 km (5 mi) of the site, provide the geometry, length, sense of movement, amount of total offset, amount of offset per event, age of latest and any previous displacements, recurrence, and limits of the fault zone.

C.I.2.5.3.7 Designation of Zones of Quaternary Deformation in the Site Region

Demonstrate that the zone requiring detailed faulting investigation is of sufficient length and breadth to include all Quaternary deformation significant to the site.

C.I.2.5.3.8 Potential for Surface Tectonic Deformation at the Site

Where the site is located within a zone requiring detailed faulting investigation, provide the details and the results of investigations substantiating that there are no geologic hazards that could affect the safety-related facilities of the plant. The information may be in the form of boring logs, detailed geologic maps, geophysical data, maps and logs of trenches, remote sensing data, and seismic refraction and reflection data.

C.I.2.5.4 Stability of Subsurface Materials and Foundations

Present information concerning the properties and stability of all soils and rock which may affect the nuclear power plant facilities, under both static and dynamic conditions including the vibratory ground motions associated with the Safe Shutdown Earthquake Ground Motion (SSE). Demonstrate the stability of these materials as they influence the safety of seismic Category I facilities. Present an evaluation of the site conditions and geologic features that may affect nuclear power plant structures or their foundations. Information presented in other sections should be cross-referenced rather than repeated.

C.I.2.5.4.1 Geologic Features

Describe geologic features, including the following:

- (1) Areas of actual or potential surface or subsurface subsidence, solution activity, uplift, or collapse and the causes of these conditions,
- (2) Zones of alteration or irregular weathering profiles, and zones of structural weakness,

DG-1145, Section C.I.2 - Site Characterization

- (3) Unrelieved residual stresses in bedrock and their potential for creep and rebound effects,
- (4) Rocks or soils that might be unstable because of their mineralogy, lack of consolidation, water content, or potentially undesirable response to seismic or other events,
- (5) History of deposition and erosion, including glacial and other preloading influence on soil deposits, and
- (6) Estimates of consolidation and preconsolidation pressures and methods used to estimate these values.

Provide description, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology.

C.I.2.5.4.2 Properties of Subsurface Materials

Describe in detail the properties of underlying materials including the static and dynamic engineering properties of all soils and rocks in the site area. Describe the testing techniques used to determine the classification and engineering properties of soils and rocks. Indicate the extent to which the procedures used to perform field investigations for determining the engineering properties of soil and rock materials are in conformance with RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants." Likewise, indicate the extent to which the procedures used to perform laboratory investigations of soils and rocks are in conformance with RG 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants."

Provide summary tables and plots that show the important test results. Also provide a detailed discussion of laboratory sample preparation when applicable. For critical laboratory tests, provide a complete description (e.g., how saturation of the sample was determined and maintained during testing, how the pore pressures changed).

Provide a detailed and quantitative discussion of the criteria used to determine that the samples were properly taken and tested in sufficient manner to define all the critical soil parameters for the site. For sites underlain by saturated soils and sensitive clays, show that all zones that could become unstable due to liquefaction or strain-softening phenomena have been adequately sampled and tested. Describe the relative density of soils at the site. Show that the consolidation behavior of the soils as well as their static and dynamic strength have been adequately defined. Explain how the developed data are used in the safety analysis, how the test data are enveloped by the design, and why the design envelope is conservative. Present values of the parameters used in the analyses.

C.I.2.5.4.3 Exploration

Discuss the type, quantity, extent, and purpose of all site explorations. Provide plot plans that graphically show the location of all site explorations such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities

DG-1145, Section C.I.2 - Site Characterization

superimposed thereon. Also, provide profiles illustrating the detailed relationship of the foundations of all seismic Category I and other safety-related facilities to the subsurface materials.

Provide logs of all core borings and test pits. Furnish logs and maps of exploratory trenches and geologic maps and photographs of the excavations for the facilities of the nuclear power plant.

C.I.2.5.4.4 Geophysical Surveys

Provide a description of the geophysical investigations performed at the site to determine the dynamic characteristics of the soil or rock. Provide the results of compressional and shear wave velocity surveys performed to evaluate the occurrence and characteristics of the foundation soils and rocks in tables and profiles. Discuss other geophysical methods used to determine foundation conditions.

C.I.2.5.4.5 Excavations and Backfill

Discuss the following data concerning excavation, backfill, and earthwork analyses at the site.

- (1) The sources and quantities of backfill and borrow. Describe exploration and laboratory studies and the static and dynamic engineering properties of these materials in the same fashion as described in Sections C.I.2.5.4.2 and C.I.2.5.4.3.
- (2) The extent (horizontally and vertically) of all Seismic Category I excavations, fills, and slopes. Show the locations and limits of excavations, fills, and backfills on plot plans and on geologic sections and profiles.
- (3) Compaction specifications and embankment and foundation designs.
- (4) Dewatering and excavation methods and control of groundwater during excavation to preclude degradation of foundation materials. Also discuss proposed quality control and quality assurance programs related to foundation excavation, and subsequent protection and treatment. Discuss measures to monitor foundation rebound and heave.

C.I.2.5.4.6 Groundwater Conditions

Discuss groundwater conditions at the site, including:

- (1) the groundwater conditions relative to the foundation stability of the safety-related nuclear power plant facilities,
- (2) plans for dewatering during construction,
- (3) plans for analysis and interpretation of seepage and potential piping conditions during construction,

DG-1145, Section C.I.2 - Site Characterization

- (4) records of field and laboratory permeability tests, and
- (5) history of groundwater fluctuations as determined by periodic monitoring of local wells and piezometers, including flood conditions.

If the analysis of groundwater at the site as discussed in this Section has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.2.5.4.7 Response of Soil and Rock to Dynamic Loading

Provide a description of the response of soil and rock to dynamic loading, including:

- (1) any investigations to determine the effects of prior earthquakes on the soils and rocks in the vicinity of the site, including evidence of liquefaction and sand cone formation,
- (2) P and S wave velocity profiles as determined from field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations), including data and interpretation of the data,
- (3) results of dynamic tests in the laboratory on samples of the foundation soil and rock, and
- (4) results of soil-structure interaction analysis.

Material on site geology included in this section may be cross-referenced in Section C.I.2.5.2.5.

C.I.2.5.4.8 Liquefaction Potential

If the foundation materials at the site adjacent to and under safety-related structures are saturated soils or soils that have a potential for becoming saturated and the water table is above bedrock, provide an appropriate state-of-the-art analysis of the potential for liquefaction occurring at the site. Indicate the extent to which the guidance provided in RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," was followed.

C.I.2.5.4.9 Earthquake Design Basis

Provide a brief summary of the derivation of the Safe Shutdown Earthquake Ground Motion (SSE), including a reference to Section C.I.2.5.2.6

C.I.2.5.4.10 Static Stability

Describe an analysis of the stability of all safety-related facilities for static loading conditions. Describe the analysis of foundation rebound, settlement, differential settlement, and bearing capacity under the dead loads of fills and plant facilities. Include a discussion and evaluation of lateral earth pressures and hydrostatic groundwater loads acting on plant facilities. Discuss

DG-1145, Section C.I.2 - Site Characterization

field and laboratory test results. Discuss and justify the design parameters used in stability analyses. Provide sufficient data and analyses so that the staff may make an independent interpretation and evaluation.

C.I.2.5.4.11 Design Criteria

Provide a brief discussion of the design criteria and methods of design used in the stability studies of all safety related facilities. Identify required and computed factors of safety, assumptions, and conservatisms in each analysis. Provide references. Explain and verify computer analyses used.

C.I.2.5.4.12 Techniques to Improve Subsurface Conditions

Discuss and provide specifications for measures to improve foundations such as grouting, vibroflotation, dental work, rock bolting, and anchors. Discuss a verification program designed to permit a thorough evaluation of the effectiveness of foundation improvement measures. If the foundation improvement verification program in this Section has not been completed at the time the COL application is filed, describe the implementation program, including milestones.

C.I.2.5.5 Stability of Slopes

Present Information concerning the static and dynamic stability of all earth or rock slopes, both natural and man-made (cuts, fills, embankments, dams, etc.) whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the nuclear power plant. Include a thorough evaluation of site conditions, geologic features, the engineering properties of the materials comprising the slope and its foundation. Present the results of slope stability evaluations using classic and contemporary methods of analyses. Include, whenever possible, comparative field performance of similar slopes. All information related to defining site conditions, geologic features, the engineering properties of materials, and design criteria should be of the same scope as that provided under Section C.I.2.5.4. Cross-references may be used where appropriate. For the stability evaluation of man-made slopes, include summary data and a discussion of construction procedures, record testing, and instrumentation monitoring to ensure high quality earthwork.

C.I.2.5.5.1 Slope Characteristics

Describe and illustrate slopes and related site features in detail. Provide a plan showing the limits of cuts, fills, or natural undisturbed slopes and show their relation and orientation relative to plant facilities. Clearly identify benches, retaining walls, bulkheads, jetties, and slope protection. Provide detailed cross sections and profiles of all slopes and their foundations. Discuss exploration programs and local geologic features. Describe the groundwater and seepage conditions that exist and those assumed for analysis purposes. Describe the type, quantity, extent, and purpose of exploration and show the location of borings, test pits, and trenches on all drawings.

Discuss the sampling methods used. Identify material types and the static and dynamic engineering properties of the soil and rock materials comprising the slopes and their

DG-1145, Section C.I.2 - Site Characterization

foundations. Identify the presence of any weak zones, such as seams or lenses of clay, mylonites, or potentially liquefiable materials. Discuss and present results of the field and laboratory testing programs and justify selected design strengths.

C.I.2.5.5.2 Design Criteria and Analyses

Describe the design criteria for the stability and design of all safety-related and Seismic Category I slopes. Present valid static and dynamic analyses to demonstrate the reliable performance of these slopes throughout the lifetime of the plant. Describe the methods used for static and dynamic analyses and indicate reasons for selecting them. Indicate assumptions and design cases analyzed with computed factors of safety. Present the results of stability analyses in tables identifying design cases analyzed, strength assumptions for materials, forces acting on the slope and pore pressures acting within the slope, and the type of failure surface. For assumed failure surfaces, show them graphically on cross sections and appropriately identify them on both the tables and sections. In addition, describe adverse conditions such as high water levels due to the probable maximum flood (PMF), sudden drawdown, or steady seepage at various levels. Explain and justify computer analyses; provide an abstract of computer programs used.

Where liquefaction is possible, present the results of the analysis of major dam foundation slopes and embankments by state-of-the-art finite element or finite-difference methods of analysis. Where there are liquefiable soils, indicate whether changes in pore pressure due to cyclic loading were considered in the analysis to assess not only the potential for liquefaction but also the effect of pore pressure increase on the stress-strain characteristic of the soil and the post-earthquake stability of the slopes.

C.I.2.5.5.3 Logs of Borings

Present the logs of borings, test pits and trenches that were completed for the evaluation of slopes, foundations, and borrow materials to be used for slopes. Logs should indicate elevations, depths, soil and rock classification information, groundwater levels, exploration and sampling method, recovery, RQD, and blow counts from standard penetration tests. Discuss drilling and sampling procedures and indicate where samples were taken on the logs.

C.I.2.5.5.4 Compacted Fill

Provide a description of the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes. Describe planned construction procedures and control of earthworks. Information necessary is similar to that outlined in Section C.I.2.5.4.5. Discuss the quality control techniques and documentation during and following construction and reference the applicable quality assurance sections of the FSAR.