United States
Nuclear Regulatory Commission

DRAFT

BRANCH TECHNICAL POSITION ON

SITE CHARACTERIZATION FOR DECOMMISSIONING

Division of Waste Management
Office of Nuclear Material Safety and Safeguards

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1 INTRODUCTION

1.1 Background

The Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 assign to the U.S. Nuclear Regulatory Commission (NRC) the responsibility for licensing and regulating commercial nuclear facilities. These activities include the decommissioning of nuclear facilities, or the process of removing the facility safely from service and reducing residual radioactivity to a level that permits release of the property in accordance with NRC requirements. NRC's decommissioning requirements are specified in the various licensing regulations in 10 CFR Parts 30, 40, 50, 70, and 72.

Over the past two decades, NRC has gained appreciable experience with the decommissioning of commercial nuclear facilities. Since 1989, NRC has placed special attention on the timely remediation and decommissioning of about 50 sites listed in the Site Decommissioning Management Plan "SDMP" (NRC, 1990a, 1991a, 1992c, and 1993). This experience in overseeing the decommissioning of SDMP sites and other licensed nuclear facilities has highlighted the importance of effective site characterization early in the decommissioning process. Figure 1 is a flow diagram showing the NRC's general decommissioning process.

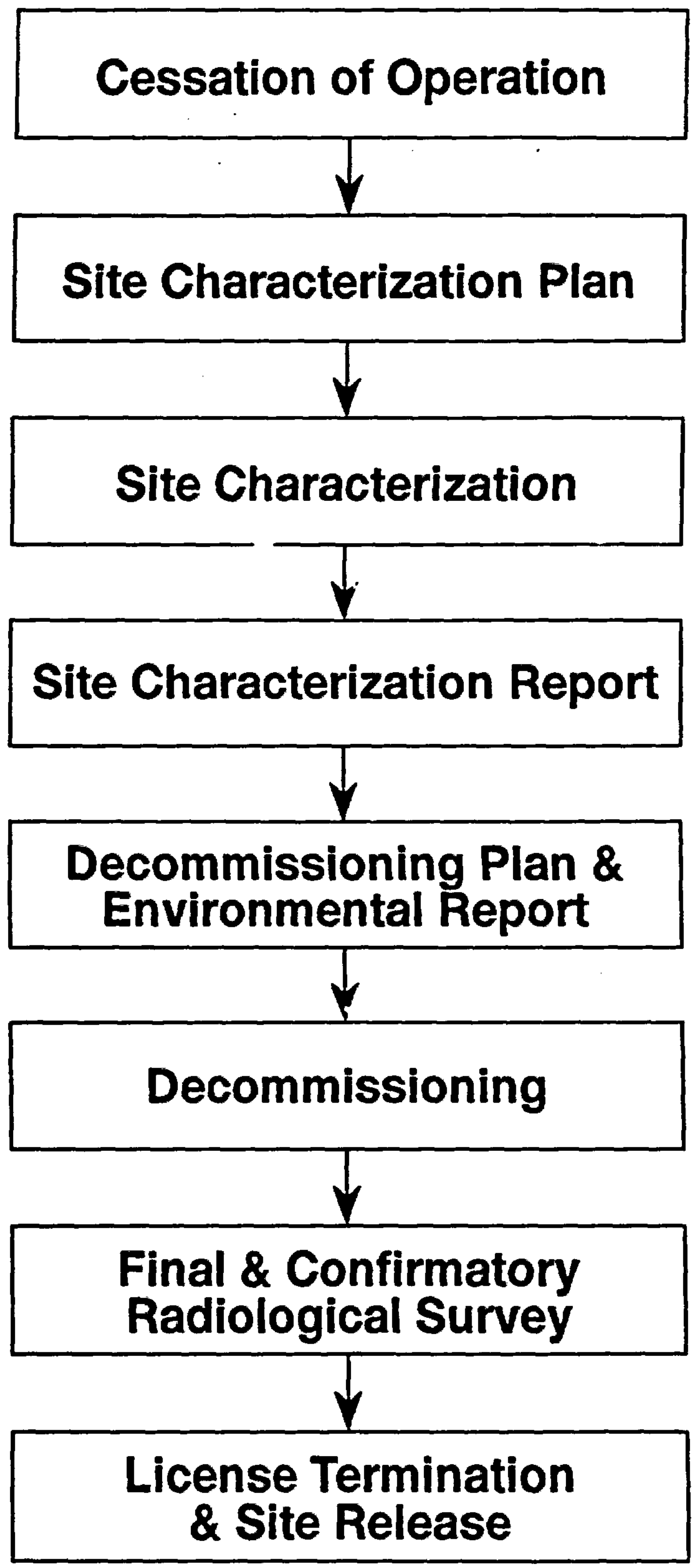
On April 16, 1992, NRC published the "Action Plan to Ensure Timely Cleanup of SDMP Sites" (NRC, 1992a). Recognizing the importance of effective site characterization to decommissioning, NRC committed in the Action Plan to providing guidance on the content of acceptable site characterization programs conducted in support of decommissioning. In July 1992, NRC completed a preliminary draft Branch Technical Position (BTP) on *Site Characterization for Decommissioning* (NRC, 1992e). NRC circulated the preliminary draft for internal review and made copies available to licensees and others upon request.

This version of the BTP constitutes an updated version of the draft guidance on *Site Characterization for Decommissioning*. NRC is circulating this version for review and comment before its issuance as final guidance.

1.2 Purpose and Scope

The purpose of this BTP, *Site Characterization for Decommissioning* (hereinafter referred to as the BTP), is to explain in more detail the type, amount, and quality of information that should be provided in typical Site Characterization Reports (SCRs) prepared and submitted to NRC by licensees and other responsible parties in support of decommissioning actions. This BTP may also serve as a template for the site characterization content of site-specific orders issued by the NRC to compel timely characterization and remediation of contaminated sites.

FIGURE 1: THE GENERAL DECOMMISSIONING PROCESS



This BTP presents a format and content for SCRs that are acceptable to the NRC staff. Fulfillment of the information needs in the format of the BTP will (1) help ensure that SCRs contain the information needed to properly plan and implement site decommissioning actions at decommissioning sites, (2) aid licensees and responsible parties and NRC in ensuring that the information in the SCR is sufficient and complete, (3) eliminate duplication of characterization efforts and minimize excessive characterization, (4) help persons locate information contained in the SCR, and (5) contribute to reducing the time needed for the regulatory review process. However, conformance with the guidance presented in the BTP is not required. The NRC staff will accept SCRs that differ from the guidance in the BTP if they present adequate site characterization information.

It should be pointed out that this BTP is not applicable to uranium recovery sites, specifically those sites associated with uranium mill operations and/or disposition of mill tailings or wastes under Titles I and II of the Uranium Mill Tailings Radiation Control Act of 1978, as amended. Although the guidance in this BTP may be helpful in characterizing uranium recovery sites, characterization of these sites for decommissioning is beyond the scope of this BTP.

Because of the site-specific characteristics of site contamination and conditions, the staff anticipates that all portions of the BTP will not be relevant at every site. Licensees and responsible parties and the NRC staff must use judgment in determining what information is specifically needed to provide an appropriate basis for site decommissioning decisions. The BTP describes a process intended to assist licensees and responsible parties in identifying and prioritizing site characterization information needs on the basis of the effect that knowing or not knowing the information will have on regulatory compliance and selection of decommissioning alternatives.

The NRC staff has selected a format for presentation of the guidance on site characterization in this BTP. The staff believes that the same format, starting with section 2.0, would be useful in structuring the information presented in SCRs. Appendix I provides a suggested site characterization report format for a typical site with extensive environmental media contamination. NRC staff reviews of SCRs with different formats may take longer because the staff is familiar with the format of information presented in this BTP. However, conformance with the BTP format is certainly not a requirement.

1.3 Site Characterization Objectives

In general, the main objectives of site characterization in support of decommissioning are:

1. To determine the type and extent of radiological contamination of structures, residues, and environmental media, including the rate(s) of migration. This information is needed to assess the

scope of proposed decommissioning actions, ensure the safety of decommissioning workers, evaluate potential environmental releases during decommissioning, and determine the adequacy of decommissioning funding or financial assurance.

2. To determine environmental conditions that could affect the rate and directions of radionuclide transport and potential human and environmental exposures to radionuclides. This information is needed to support evaluation of alternative decommissioning actions and detailed planning of a preferred approach for decommissioning, decontamination, and waste disposal.

These objectives are ultimately linked to the decommissioning decisions that are relevant to each site, which are expected to vary based on the type and extent of contamination, physical characteristics of the affected environment, and the general approach for decommissioning. At sites that will be remediated to allow release for unrestricted use in accordance with NRC requirements, detailed environmental information developed under the second objective will be less important. In contrast, such information will be essential if the proposed decommissioning approach includes stabilization on site of a significant inventory of radioactive material.

Site characterization as used throughout this BTP may also include assessment of associated non-radiological constituents, if necessary, to determine their effects on the environmental transport and bioavailability of radiological constituents, to evaluate potential environmental impacts associated with decommissioning, or to comply with requirements of other agencies. It should be emphasized, however, that NRC does not enforce the requirements of other agencies except when they are incorporated within NRC regulations or as license conditions.

2. GENERAL APPROACH TO SITE CHARACTERIZATION

2.1 Regulatory Requirements

NRC requirements for decommissioning are established in 10 CFR Parts 30, 40, 50, 70, and 72. For materials licensees under Parts 30, 40, and 70, NRC requires submission of proposed decommissioning plans that include

> "a description of the conditions of the site or separate building or outdoor area sufficient to evaluate the acceptability of the plan" [see, for example, 10 CFR 40.42(f)(4)(i)].

This description of the conditions includes site characterization information, such as the nature and extent of radiological contamination and any other information necessary to evaluate the proposed decommissioning activities.

Materials licensees regulated under 10 CFR Parts 30, 40, and 70 are also required to develop and maintain records important to the safe and effective decommissioning of the facility. These records include:

- Records of spills or other unusual occurrences involving the spread of contamination in and around the facility, equipment, or site. These records include any known information on the identification of involved radionuclides, quantities, forms, concentrations [see, for example, §40.36(f)(1)];

- As-built drawings and modifications of structures and equipment in restricted areas where radioactive materials are used and/or stored and of locations of possible inaccessible contamination such as buried pipes which may be subject to contamination [cf. §40.36(f)(2)]; and

- A list of all areas designated or formerly designated as restricted areas, all areas outside the restricted area that require documentation {e.g., per §40.36(f)(1)}, all existing and former waste disposal areas outside of the restricted area, and all areas outside the restricted area that would either require decontamination to unrestricted release levels or apply for approval for waste disposal under 10 CFR 20.2002 [cf. §40.36(f)(3); note that these subsections exclude depleted uranium used as shielding, unused depleted uranium munitions, sealed sources, and radioactive materials with short half lives].

Where this information is not already available and documented, licensees may need to develop the information through site characterization in support of decommissioning.

For reactors and independent spent fuel storage installations (ISFSI), which are licensed under 10 CFR Parts 50 and 72, respectively, NRC regulations in §50.75(g) and §72.30(d) require that licensees keep records of information important to the safe and effective decommissioning of the facility in an identified location until the license is terminated by the Commission. These records include:

- Records of spills or other unusual occurrences involving the spread of contamination in and around the facility, equipment, or site. These records include any known information on the identification of involved radionuclides, quantities, forms, concentrations [§50.75(g)(1) and §72.30(d)(1)], and

- As-built drawings and modifications of structures and equipment in restricted areas where radioactive materials are used and/or stored and of locations of possible inaccessible contamination such as buried pipes which may be subject to contamination [§50.75(g)(2) and §72.30(d)(2)].

ISFSI licensees also need to maintain and update a list of contaminated areas outside of the restricted area similar to materials licensees [cf. §70.30(d)(3)].

Where this information is not already available and documented, licensees may need to develop the information through site characterization in support of decommissioning.

2.2 Planning for Site Characterization

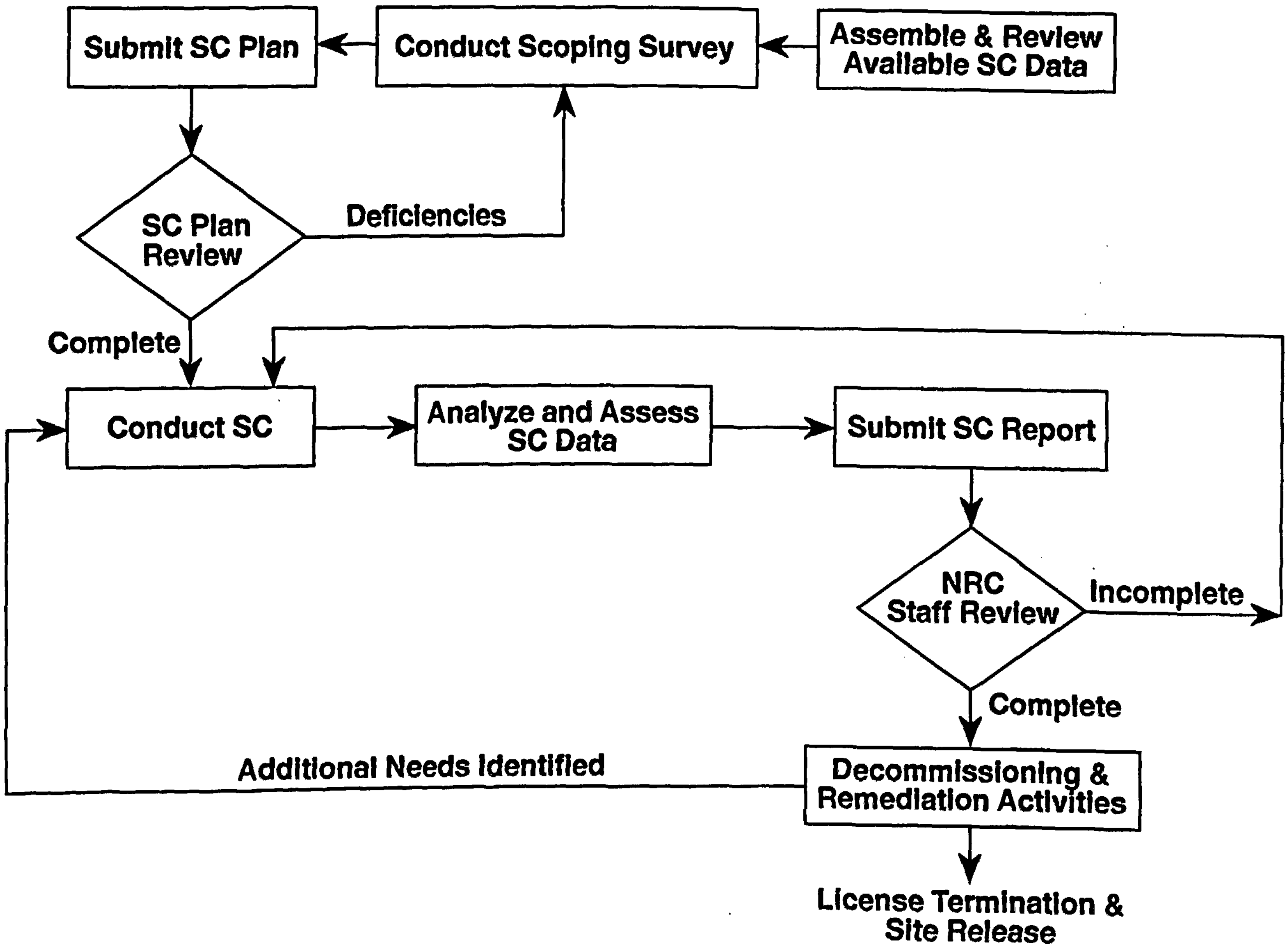
Site characterization is inherently, to some extent, an iterative process. Figure 2 shows a conceptual flow diagram of the iterative process of site characterization for the decommissioning. The site characterization process typically begins with assembly and review of available information on site history, physical environment, type and extent of radiological contamination, and location of potentially exposed populations. If generic information on type and extent of contamination is not available, such information may be obtained by conducting a scoping survey. Based on the available information (e.g., historic data), preliminary measurements, and the scoping survey, licensees should be able to prepare a "Site Characterization Plan (SCP)" explaining plans for site characterization, including assessment activities, techniques and methods to be employed and the time schedule for completion of these activities. The content of the SCP should be consistent with the characterization aspects in the BTP and should cover all affected environmental media as discussed in the BTP. NRC staff will review the SCP, and identify deficiencies, if any, so that the licensee (or responsible party) can perform additional review and possibly modify the plan.

In developing plans for site characterization, licensees and other responsible parties should consider conceptual plans for decommissioning in order to meet NRC decommissioning criteria and guidelines. In addition, other relevant factors such as the type and future extent of radiological contamination and potential for short-term and long-term exposure of humans after the site is released should also be considered. These considerations are important in determining the objectives of the site characterization program on a site-specific basis and in establishing the site characterization data quality objectives in the early stage of site characterization.

Effective site characterization requires planning to ensure that efforts will develop the appropriate types and amounts of information needed to support decommissioning decisions. Determining what constitutes adequate site characterization is dependent to a large extent on site-specific conditions. Licensees and other responsible parties may find it useful to prioritize information needs by conducting preliminary assessments of potential human exposures for the preferred decommissioning approach.

The preliminary assessment is usually conducted using screening-type codes for radiological pathways analysis and dose exposure calculations [e.g., the NRC D&D Screen Code that implements the methodology in NUREG/CR-5512 (NRC, 1992b) and the Department of Energy's RESRAD code (DOE, 1989 and Yu et.al., 1993)].

FIGURE 2: CONCEPTUAL FLOW DIAGRAM OF THE INTERACTIVE PROCESS OF SDMP SITE CHARACTERIZATION



Because of the limited information available at this early stage, the assessment generally is based on a number of assumptions that tend to overestimate the potential impacts associated with contamination. The assessment should provide estimated human exposures for each significant transport pathway under a variety of exposure conditions (i.e., exposure scenarios). NRC's Policy Guidance Directive PG-8-08 (NRC, 1994a) outlines various exposure scenarios and exposure parameters recommended for use in the dose impact assessment.

Although such preliminary assessments may be of limited accuracy, they can be used to help identify and set priorities for site characterization needs based on the relative importance and significance of exposure pathways indicated by the assessments. Site characterization should be planned in a manner that maximizes the utility of the information to be collected and optimizes its adequacy and quality during the site characterization process. For example, for a particular site, a licensee or responsible party may show that the surface water pathway is not likely to be significant in terms of existing and potential future exposure to members of the public. In such a case, the need for detailed characterization of the surface water system is decreased.

Such planning may significantly reduce the amount and types of information needed to support decommissioning, provided that sufficient information on transport and exposure pathway parameters is available to justify the results of the preliminary assessment. At a later stage, when more site data become available, more detailed dose assessments, based on site specific conditions, may be needed to demonstrate compliance with the decommissioning dose criteria or evaluate alternative decommissioning actions.

Licensees and other responsible parties are encouraged to consult with the NRC staff early in the process of planning site characterization. In many cases, licensees and responsible parties may benefit by conducting a preliminary scoping survey of radiological contamination and submitting a Site Characterization Plan (SCP) for NRC review in advance of commencing site characterization activities. Through review and discussion of the SCP, NRC and the licensee (or the reposible party) should reach agreement on appropriate approaches for site characterization early in the site characterization process, thus potentially avoiding the need for unnecessary and costly delays and additional characterization campaigns after the initial Site Characterization Report (SCR) has been completed and submitted. NRC staff also encourages licensees to meet periodically with the staff during site characterization activities to ensure that the activities are progressing in a timely and reasonable manner and to resolve issues that may arise during site characterization. NRC staff will also perform inspections (announced and unannounced) during site characterization to ensure that all activities comply with NRC's requirements.

As an example of effective interactions during site characterization, identification of groundwater contamination during preliminary scoping survey may warrant installation and sampling of additional monitoring wells to define the extent and migration status of the contamination. Resolving such issues as appropriate locations and numbers of these additional monitoring wells, while site characterization contractors are still onsite, may help avoid unnecessary expense, such as remobilization costs, that may otherwise be incurred at a later time after the initial SCR is submitted. All licensee (or responsible party) submittals will be included in the licensing docket and will be publicly accessible, unless the licensee or responsible party is permitted to withhold disclosure in accordance with NRC requirements in 10 CFR Part 2. Meetings between NRC and the licensee or other responsible party will be open to public observance in accordance with NRC's Open Meeting Policy (59 FR 48340; September 20, 1994).

2.3 Site Characterization

When the SCP is approved, licensees should commence site characterization according to the plan. During the characterization process, licensees should assess and analyze the data as early as possible to develop a sufficient and defensible characterization of the site. It is expected that site characterization plans may change during conduct of the characterization as a result of these ongoing assessments. Departures from the plan may be appropriate, for example, where contamination is more extensive than originally anticipated and greater numbers of samples are necessary to characterize the full extent of the contamination. Significant changes in the plan should be discussed with the NRC staff before their implementation.

Through this iterative approach, licensees and responsible parties should increase the likelihood that the site characterization will be reasonably complete at the time of SCR submittal and will provide a defensible basis for designing and evaluating site decommissioning alternatives.

Site characterization approaches should also be flexible enough to permit the licensee or responsible party to promptly remediate contamination identified during the course of site characterization. This flexibility is especially important if characterization identifies relatively small volumes of contaminated materials which can be classified as low-level radioactive waste and will obviously need to be disposed of in a licensed disposal facility for low-level radioactive waste. For example, a licensee may discover several cubic feet of soil contamination that is well in excess of applicable cleanup criteria (e.g., uranium concentrations ten times greater than the Option 2 levels of the 1981 Branch Technical Position on Uranium and Thorium Wastes). If the licensee's preferred decommissioning approach for this contaminated soil would be to remove it to a licensed disposal facility, the site characterization approach should allow the licensee to excavate the contaminated material in accordance with established radiation protection procedures and transfer the waste for disposal in accordance with existing regulations and license conditions. The licensee should properly document the detection, extent, removal, and transfer of the contaminated soil to allow confirmation, during subsequent review of decommissioning activities, that the material was removed and disposed of in an appropriate manner.

In other cases, the licensee may prefer to consider the disposition of the contaminated material in the broader context of a range of decommissioning alternatives, rather than commit to a specific course of action during characterization. In such a case, the licensee's site characterization report would document the detection and extent of the contamination. Decisions on the disposition of the contaminated soil would then be addressed in developing and reviewing the licensee's Decommissioning Plan.

2.4 Site Characterization Report

After completion of the characterization activities and subsequent assessment of the results, the licensee (or responsible party) prepares an SCR and submits the SCR for NRC staff review. Staff will assess the SCR to determine if it is complete and contains sufficient information to characterize the full extent of radiological contamination and covers all possible affected environmental media. Staff will also assess the information to determine if it is sufficient to support evaluation of reasonable decommissioning approache. or alternatives.

If the SCR is incomplete, the NRC will inform the licensee (or the responsible party) of the deficiencies and will request additional characterization information and data. If the SCR is complete (i.e., adequately describes the extent and nature of contamination and the characteristics of the affected environmental media), the licensee would proceed to the next step of the decommissioning process as illustrated in Figure 1.

The adequacy of site characterization efforts, and ultimately decommissioning actions, is determined based on comparison with applicable decommissioning criteria and requirements such as the interim NRC decommissioning criteria described in the Site Decommissioning Management Plan Action Plan, 57 FR 13389, April 16, 1992 [NRC interim criteria are listed in the Reference Section (e.g., NRC, 1974, 1981, 1982a, 1983a, 1987, and EPA, 1976 and 1977b)]. NRC is presently conducting a rulemaking to establish radiological criteria for decommissioning (59 FR 43200; August 22, 1994). The results of this rulemaking are expected to replace the interim criteria described above.

In some cases, site characterization may indicate compliance with NRC decommissioning criteria. In most cases, however, the licensee or the responsible party will follow the submission of an SCR with the development of a remediation or decommissioning plan and environmental report (if necessary) that describes the approaches to be used to comply with applicable decommissioning criteria by removing or stabilizing the contaminated material (e.g., 10 CFR 20.2002). In the case where the decommissioning action involves onsite stabilization of a significant inventory of radioactive material, the licensee (or responsible party) may need to conduct (as part of the remediation plan development) additional site characterization (e.g., groundwater modeling and characterization and geotechnical engineering analysis). These additional characterization activities may also be necessary to support detailed design of decommissioning actions (e.g., groundwater restoration or construction of an onsite disposal cell).

The remainder of this BTP provides guidance on the content and format of acceptable SCRs. The information is discussed under the main headings of:

- General Information - Site history and description, and physical setting
- Nature and Extent of Contamination - Contamination sources, survey design, surface water and sediments, soils and vadose zone, groundwater, structures and equipment, air
- Physical Characteristics - Surface features, meteorology and climatology, surface water hydrology, geology, demography and land use, hydrogeology, geotechnical engineering
- Dose Assessment - Exposure setting, identification of pathways, quantification of exposures

3. GENERAL INFORMATION

3.1 Site History and Description

NRC requirements in 10 CFR Parts 30, 40, and 70 require the submittal of information regarding the site history and its operation. Therefore, SCRs should provide background information describing the specific site location, site history (related to operations that could have resulted in on-site radiological contamination), and previous investigations relevant to radioactive and hazardous waste activities. Other information pertaining to the decommissioning process as required by the recordkeeping requirements for decommissioning should also be provided or referenced (e.g., records of spills, contamination distribution, former disposal areas). Such information should include maps, drawings, and aerial photographs if available.

3.1.1 Site Location and Description

Information on site location and description consists of the following:

(a) Specific site location, including legal land description, survey information, street address, nearest town, local political jurisdiction (e.g., county, township, borough, district), State, U.S. Geological Survey (U.S.G.S) 7 1/2-minute quadrangle, and distances and directions of the site to reference points or coordinates.

(b) General area, dimensions, and locations of contaminated areas on the site and any contaminated areas offsite (additional detail on contamination to be provided under Section 4).

(c) The map should also show site ownership, boundaries, and surroundings, including roads, railroads, utility lines, drainage ways, canals, sites of historical significance, and other features that could affect the conduct or effectiveness of decommissioning activities. All major structures owned or used by the licensee, or responsible party, (including structures not associated with licensed activities e.g., water storage tanks and warehouses) should be shown on the map which shows the site and its vicinity.

(d) Topography of the site and its immediate surroundings, including hydrogeologic features such as rivers, dams, wet-lands, drinking and supply water intakes and locations of offsite population centers. Topographic maps should be at a scale of 1:200 with a contour interval of about 5 feet (or other interval that appropriately indicates the relief and grades on and immediately adjacent to the site), along with the portion of the 7 1/2-minute U.S.G.S Quadrangle that contains the site and its immediate surroundings.

3.1.2 Site History

This section of the SCR should summarize significant historical facts and records that may affect the design of decommissioning actions or help explain the nature and extent of site contamination. This information includes records on site conditions prior to licensed activities, operation of the facility, records on effluents and onsite disposal, and significant incidents of releases or spills. Specifically, this information should include:

(a) Records about onsite activities and past operations involving operations such as demolition, effluent releases, production of residues, landfilling, waste and material storage, pipe and tank leaks, spills, and accidental releases, flooding, and onsite radioactive and hazardous waste disposal. Past operations should be summarized in chronological order along with type of permits and/or approvals that authorized these operations. Estimates of the total activity of radioactive material released or disposed of on the site and its physical and chemical forms should also be included. The SCR should also analyze historical records on environmental monitoring, site inspection reports, license applications, operational permits, material balance and inventory sheets, and other records. Accidents like fires, spills, unintentional releases, or leakage should also be investigated as potential sources of contamination. The presence of buried materials or subsurface contamination should also be described in detail. Besides reviewing the records, interviews of longtime employees may be beneficial in supplementing the historical records regarding the extent and cause of contamination.

(b) Historical attempts, if any, to characterize the site and summaries of previous site monitoring programs, including sampling and analytical records of environmental monitoring programs reported for the site or the immediate surroundings.

(c) Records of relevant inspections, surveys, and investigations conducted by the licensee, responsible parties, or previous or present owner.

(d) Historic aerial photographs and site location maps showing previous site development and activities (if available).

3.2 General Physical Setting

The SCR should summarize the general physical setting of the site, including general physical characteristics of the site and its proximity to people who could be affected by existing contamination or decommissioning activities. The intent of this section is to provide a summary overview of the site characteristics.

3.2.1 Physical Site Characteristics

The section should summarize the following physical characteristics in general terms:

- Climate (e.g., temperature, precipitation).
- Geologic setting (e.g., unconsolidated deposits and bedrock strata).
- Vegetation (e.g., unvegetated, forested, grassy).
- Soil (e.g., composition, thickness, chemistry).
- Groundwater (e.g., depth, quality, uses, and direction and rate of flow).
- Location and description of surface water (e.g., type, flow rates, quality, and uses).

3.2.2 General Information on Exposed Populations

This section of the SCR should provide a summary description of the general characteristics of potentially exposed populations. These characteristics include:

- General distribution and number of people near the site.
- Current land use(s) adjacent to the site.

- Anticipated future land use(s) on and adjacent to the site.
- Location and characteristics of any subgroups of special concern.

4 NATURE AND EXTENT OF CONTAMINATION

4.1 Source of Contamination

The complexity and depth of detail of contamination characterization will depend primarily upon the extent and concentration of contamination. Typically, before going through much detailed site characterization, the first phase of a study of the extent of contamination is to analyze the type of nuclear facility and nature of the process(es) that may have caused radiological and associated non-radiological contamination. The SCR should assess the process(es) to determine their effect on site contamination in terms of the following information: physical and chemical properties of the waste constituents, type and relative quantities of radionuclides used in the process, heterogeneity of the contaminants and waste materials, types and relative quantities of reagents used in the process, specific raw material composition used, location of effluent discharges and releases, relative throughput of activity and materials, and waste management practices.

4.1.1 Waste Characterization

Waste characterization should include the following information: (1) identification of radiological and selected non-radiological constituents in the waste (see secion 5.6.1.3 of the BTP), including any degradation products of the constituents; (2) assessment of the leaching potential [e.g., ANSI/ANS (1986); Baes and Sharp (1983) and EPA (1990)] and the solubility and the potential environmental availability (e.g., NRC 1980a, 1980b, and 1994) of the radiological constituents from the waste, described as a relationship between estimated aqueous concentrations of constituents and the composition of the waste; and (3) spatial distribution of constituents in the waste. Additional information on waste characteristics may also be necessary to support acceptable waste characterization depending on the significance of the contamination and the potential for transport and human exposure to the contamination. Such information may include, but not limited to, the following: (1) chemical and physical characteristics such as solubility, valence state, and density (NRC, 1994); (2) presence and effect of complexing ligands and chelating agents, to the extent that they may enhance or retard constituent mobility; (3) potential for constituent degradation as a result of chemical, biological, and physical processes; and (4) attenuation properties of constituents {e.g., distribution coefficient (Sheppard and Thibault, 1990), and affected hydrogeologic media to characterize processes as ion exchange, adsorption, absorption, precipitation, and dissolution (Sheppard and Thibault, 1988 and 1992).

At sites where releases of radiological constituents have contaminated appreciable volumes of groundwater, surface water, soils, sediments, or rocks, characterization of the extent of contamination should include assessment of the distribution of radiological and associated non-radiological constituents in groundwater, soils, and surface water and sediments at the facility.

4.1.2 Extent of Contamination

Characterization of the extent of contamination should provide sufficient information on: (1) distribution and concentration of radiological constituents in surface water and sediments; (2) concentration and distribution of radiological contaminants in soils and other unconsolidated deposits; (3) concentration and distribution of radiological constituents in bedrock and groundwater; and (4) distribution of radiological constituents in contaminated equipment, buildings, structures, and other site facilities. The characterization should include sufficient information on radiological and physio-chemical analytical data to ensure their reliability and representativeness, including sampling analysis methodology and quality assurance programs. Characterizations should clearly identify the full extent of contamination by distinguishing portions of environmental media (e.g., soil, structures, water) that have been affected by radiological contamination from media that have not been affected. Concentrations and surface activities would be expected to be at background levels in unaffected areas. The characterization should confirm that radionuclide concentrations and surface activities are not elevated outside of areas that have been affected.

4.2 Survey Design

The design of a survey and sampling program should be based on specific Data Quality Objectives (DQOs) in connection with type, content, and amount of data to be obtained. The DQO process is usually conducted (e.g., EPA 1987a,b and 1989b) to ensure that an adequate amount of data with appropriate quality are collected for the identified purpose of characterization. The radiological survey should be conducted on a specified grid and should include sampling (systematic and biased) of contaminated surfaces (e.g., buildings, structures, and equipment) and environmental media associated with surface and subsurface contamination. The purpose of survey and sampling is to determine the nature and extent of radiological contamination. This information will be used in evaluating proposed decommissioning activities, assessing potential occupational and public doses, comparing decommissioning alternatives, designing remediation, and developing cost estimates for decommissioning in accordance with NRC requirements.

The extent of site contamination should be determined using an appropriate combination of field survey and sampling techniques for each medium. Licensees and other responsible parties should consult *Guidance Manual for Conducting Radiological Surveys in Support of License Termination*, NUREG/CR-5849 (NRC, 1992d), for guidance on general aspects of site radiological characterization. Although NUREG/CR-5849 provides guidance on final termination surveys that are conducted at the end of decommissioning, many of the concepts and approaches employed in the guidance is useful in designing survey and sampling plans for radiological characterization in support of decommissioning. In general, site characterization will not require the level of detail prescribed in the NUREG/CR-5849 for the final and confirmatory survey. Nevertheless, data collected using the methods described in NUREG/CR-5849 as part of site characterization may be used in support of license termination provided they have been collected under a suitable quality assurance program and administrative controls. Other useful guidance documents on field survey and sampling are listed in the Reference Section of the BTP; the list includes: (EPA, 1984a, 1985, 1988a, and 1989a; DOE, 1981 and 1983; NRC, 1994d; Gilbert and Simpson, 1992; Cohen and Associates, 1994; Korte and Ealey, 1983; and Korte and Kearl, 1984).

4.2.1 Survey Design

The design of radiological survey and sampling should be based on specific data quality objectives based on the purpose, type, and amount of data to be obtained. The design of a contamination survey is initiated by subdividing the contaminated site into survey units and strata based on the potential for and type of contamination. A grid system should be established to provide a traceable reference for measurements/sampling locations and a convenient method of determining the average contamination levels and for future relocation of survey and sampling points. A method for designing an acceptable grid system is that described in NUREG/CR-5849 (NRC, 1992d). It should be recognized that the grids are intended for reference purposes only and not to dictate the spacing of survey or sampling points. Closer-spaced survey locations may be required for characterizing areas of known discrete contamination or hot spots. For gamma-emitting radionuclides, the results of a general area exposure-rate survey may be used to identify areas requiring more dense sampling based on the presence and extent of contamination in those areas.

4.2.2 Sampling Frequencies

The SCR should provide sufficient data to demonstrate on a statistical basis that characterization data are sufficiently representative of the waste and contaminated environmental media to estimate the inventory of radionuclides and the extent of radiological contamination. Gilbert and Simpson (1992), NRC (1992), Gilbert (1987), and EPA (1991) provide useful information regarding statistical procedures for sampling environmental media. Contamination at decommissioning sites typically tends to be localized in a small portion of the site. The number of survey and sampling points per unit area or volume will depend upon the anticipated extent of contamination, cause of contamination, and its location (e.g., inside or outside the restricted areas). NUREG/CR-5849 provides details on frequency and sampling for buildings and soil. In general, one-time sampling should be sufficient to characterize the extent of contamination in buildings, structures, soil, and unconsolidated deposits (e.g., fill), unless available site characterization information indicates that the contamination is migrating.

In contrast, groundwater and surface water quality and water levels should be determined on a set frequency established based on site-specific considerations. For sites with extensive groundwater contamination, a network of monitoring wells should be designed and installed to provide a high probability of detecting and characterizing existing contamination and determining background groundwater quality. Groundwater levels should be measured in piezometers and monitoring wells that provide a sufficiently accurate indication of hydraulic head to characterize the hydraulic gradient within the uppermost aquifer and adjacent units. Water levels should be measured on a weekly basis for two months to determine temporal variations in the hydraulic gradient. After this period, the frequency of water level measurements should be adjusted to reflect anticipated temporal variation in hydraulic heads (e.g., tides, river bank storage, water year variations). Acceptable methods for groundwater sampling and for measuring water levels are described in the EPA documents (EPA, 1977a, 1985, 1986, and 1987b), in the *National Handbook of Recommended Methods for Water-Data Acquisition* (U.S.G.S, 1977), and in *Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and For the Installation of Monitoring Wells*, GJ/TMC-08, Bendix Field Engineering Corporation, (Korte and Kearl, 1984).

The sampling frequency for determining variations in groundwater quality should be determined based on the temporal variation in hydraulic gradients, as well as temporal variations in hydrochemistry and migration of radiological and associated non-radiological constituents. After an initial sampling round in which each monitoring well is sampled, representative samples should be collected and analyzed once every other week from key monitoring wells for a two-month period to estimate the temporal variation of water quality in the uppermost aquifer and adjacent units. After this initial period, sampling frequency should be adjusted to reflect variations in the hydraulic gradient and hydrochemistry. Concentrations of principal radiological constituents should not change by more than about 10 - 20% between sampling events. If the concentrations change by more than 10 - 20%, the frequency of sampling should be increased in attempt to characterize the temporal variability of groundwater quality. For most sites, sampling on a quarterly basis (i.e., one sample per well per calendar quarter) should be sufficiently frequent to characterize temporal changes in water quality. More frequent sampling may be necessary, however, especially at sites involving off-site or potential off-site contamination of groundwater resources. Acceptable methods for groundwater sampling are described in the *National Handbook of Recommended Methods for Water-Data Acquisition* (U.S.G.S, 1977), *Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and For the Installation of Monitoring Wells* (Korte and Kearl, 1984), and EPA references mentioned above.

Quarterly sampling of surface water and sediments should be sufficient at most sites. This sampling should be supplemented by additional sampling to characterize the surface system at representative high or low stage flow conditions (i.e., minimum annual, 7-day average low flow; maximum annual, 7-day average high flow). This information should be used to bound the existing and projected impacts of the release of contamination on adjacent surface water bodies.

4.3 Surface Water and Sediments

For sites that are located near surface water streams and could reasonably affect surface water pathways, the site characterization program should establish background surface water quality by sampling upstream of the site being studied or areas unaffected by any known activity at the site. Water should be collected as grab samples from the stream bank in a well-mixed zone. Depending on the significance of, and potential for, surface water contamination, it may be necessary for certain sites to collect stratified samples from the surface water to determine the distribution of contaminants within the water column. Surface water quality sampling should be accompanied by at least one round of stream sediment quality sampling to assess the relationship between the composition of the dissolved solids, the suspended sediment, and the bedload sediment fractions. Water levels and discharge rates of the stream should be determined at the time samples are collected. Acceptable methods for surface water and sediment sampling are described in the *National Handbook of Recommended Methods for Water-Data Acquisition* (U.S. G.S, 1977), and *Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and For the Installation of Monitoring Wells*, (Korte and Kearl, 1984). In addition, Fleishhauer and Engelder (1984) presented suggested procedures for stream sediment sampling in *Procedures for Reconnaissance Stream-Sediment Sampling*. The EPA guidance documents mentioned above are also applicable.

Surface water sampling should be conducted in areas of runoff from active operations. In case of direct discharge into a stream, the outfall and the stream should be monitored and sampled upstream and downstream from the outfall. Radiological screening for contamination levels should be conducted by measuring gross alpha and total beta particle activity (total and dissolved) and by obtaining a gamma spectrum for surface water samples. Specific radionuclide analysis may be needed depending on level of activities and type of radionuclides. Non-radiological parameters, such as specific conductance, pH, and total organic carbon may be used as surrogate indicators of potential contamination, provided a clear relationship is established between radionuclide concentration and the level of the surrogate. Additional analysis for other parameters like volatile and semi-volatile compounds, chelating agents, pesticides, and polychlorinated biphenyls (PCBs) may also be necessary if they affect the mobility of radiological constituents and to evaluate potential environmental effects of the decommissioning.

The SCR should provide contour maps showing contaminant concentration profiles. Surface water flow models can be used to assist in estimating contaminant concentrations or migration rates.

4.4 Soils and Vadose Zone

The soil is the unconsolidated and weathered upper layer of the earth in which plants grow and abiotic degradation commonly occurs. The soil usually extends 1-2 m down from the surface and occasionally referred to as the "root zone." The vadose zone is the unsaturated or partially saturated zone between the land surface and the regional water table. Generally, fluid pressure in this zone is less than atmospheric pressure; some of the voids in the vadose zone contain air or other gases at atmospheric pressure.

The SCR should determine the extent (lateral and vertical) and concentrations of radiological and associated non-radiological constituents in the soil and other unconsolidated deposits (e.g., fill). Representative soil samples should be analyzed to determine the concentration and distribution of radionuclides and associated non-radiological constituents in soil at and below the surface using the grid systems described in Section 5.1. Ranges of concentrations should be reported and isopleth plots[1] should be presented for significant radionuclides. Where surface contamination is present or where subsurface contamination is known or suspected, subsurface soil samples should be collected and analyzed to depths until it can be demonstrated that concentrations representative of background are attained for all radionuclides. Subsurface contour plots for each depth range should also be developed.

Boreholes at depths down to the water table should be constructed to provide samples representing subsurface deposits. The depth of these boreholes should vary depending on the extent of the contamination, source of the contamination, and hydrogeologic conditions. Subsurface samples should generally be collected using vertical intervals no greater than 5 feet, unless finer resolution is required to delineate the variation and extent of contamination. For example, a finer sampling resolution would be appropriate in characterizing subsurface contamination at a site where fill was placed beneath the facility several times during its operational history and borehole gamma scans indicate the contamination may be limited to several thin (e.g., less than 1 foot) layers. Subsurface samples should be analyzed to determine the concentration and physical/chemical state of the radiological and associated non-radiological constituents. The SCR should explain observed vertical and lateral variations of contaminant concentrations.

Contaminated soil should be identified by comparing existing concentrations of radiological and associated non-radiological constituents with representative background concentrations. Background concentrations should be determined for a sufficient number (e.g., 30) of soil samples that are representative of the soil (or other unconsolidated deposits) in terms of parent material, soil

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1 *The isopleth plots are plots or isograms showing lines on a map where each line indicates a specified constant value of a variable or parameter (e.g., concentration of a radionuclide).*

type, bulk composition, structure, and pedologic description and that are representative of the soil composition that has not been affected by any facility or operation. Background concentrations should be determined for each type of soil, unconsolidated deposit, or bedrock that may reasonably be contaminated by the facility. Additional guidance on selecting background locations and developing estimates of background radionuclide concentrations is provided in NUREG/CR-5849 (NRC, 1992d), NUREG-1501 (NRC, 1994c), and NUREG/CR-1505 (NRC, 1994d). Appendix II presents examples of radiological survey forms used in soil and vadose zone characterization.

4.5 Groundwater

Characterization of groundwater contamination should be adequate to determine:

1. The extent and concentration distribution of contaminants.
2. Background groundwater quality.
3. Rate(s) and direction(s) of contaminated groundwater migration.
4. Assessment of present and potential future effects of groundwater withdrawal on the migration of groundwater contaminants.

The extent of contamination and background groundwater quality should be determined based on groundwater monitoring data from a suitable monitoring well network. Guidance documents on acceptable groundwater monitoring techniques are listed in the References Section [e.g., Korte and Ealey (1983), Korte and Kearl (1984), U.S.G.S. (1977), EPA (1977a, 1980, 1985, and 1986) and NRC (1989b and 1989c)]. The actual number, location, and design of monitoring wells depend on the size of the contaminated area, the type and extent of contaminants, the background groundwater quality, the hydrogeologic system, and the objectives of the monitoring program. For example, if the objective of monitoring is only to indicate the presence of groundwater contamination, relatively few downgradient and upgradient monitoring wells are needed. In contrast, if the objective is to develop a detailed characterization of the distribution of constituents within a complex aquifer as the design basis for a corrective action program, a large number of suitably designed and installed monitoring wells and well points may be necessary. Planned site characterization activities should be flexible enough to allow for the installation of additional monitoring wells during the characterization effort if preliminary characterization indicates contamination where previously unanticipated or if necessary to delineate the vertical or lateral extent of contaminant plumes. Monitoring well locations, contaminant concentrations, and contaminant sources should be plotted on a map (or series of maps for multiple contaminants) to show the relationship among contamination, sources, hydrogeologic features and boundary conditions, and property boundaries. The map should generally be prepared using the site base map described in Section 3.1 and at a scale of 1:200. At sites with significant vertical migration of contaminants, the SCR should also provide hydrogeologic cross-sections that depict the vertical distribution of contaminants in groundwater. The vertical exaggeration of the sections should not exceed 10 times.

The SCR should also describe the groundwater characterization program used to characterize the extent and distribution of contaminants in the groundwater. The description should provide monitoring well completion diagrams explainingelevation, internal and external dimensions, types of casings, type of backfill and seal, type of the screen and its location and size, borehole diameter and elevation and depth of hole, and type and dimension of riser pipe and other necessary information on the wells. An acceptable generic completion design is illustrated in Figure 3.

Sampling techniques, methodology, and procedures should be documented or referenced in the SCR. Site characterization procedures and methods should generally adhere to acceptable National practices and standards [e.g., American Society for Testing and Materials (ASTM), U.S. Geological Survey (U.S.G.S.), Environmental Protection Agency (EPA), Department of Energy Environmental Monitoring Laboratory (DOE/EML), and National Institute of Standards and Technology (NIST)]. The SCR should identify specific analytical methods that conform to generally accepted protocols and methods, such as those endorsed by EPA, NIST, DOE/EML, or other methods established through comprehensive peer review and recommendation process (e.g., ANSI/ASME 1986). Appendix III to this BTP provides sample forms for documenting well summary information, samples, chain of custody, quality assurance information for field chemical analyses, and sample location and identifier [from *Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and For the Installation of Monitoring Wells*, (Korte and Kearl, 1984)].

The scope of the characterization effort should include all significant radiological constituents, along with inorganic and organic constituents and parameters that may be of value in (1) defining the extent of contamination, (2) assessing the health and environmental risk posed by the radiological contaminants, (3) determining the effect of the non-radiological constituents on the mobility of the radionuclides, and (4) evaluating potential environmental effects associated with the decommissioning effort. Characterization of these non-radiological constituents and parameters may also be required separately by other regulatory agencies that have jurisdiction over the decommissioning effort. Typical analytical parameters include gross alpha particle activity, gross beta particle activity, specific isotopic concentrations, gamma spectrum analysis for all gamma-emitting radionuclides suspected to be present, sulfate, chloride, carbonate, alkalinity, nitrate, TDS, Total Organic Carbon (TOC), Eh, pH, calcium, sodium, potassium, iron, and dissolved oxygen. Additional analytical parameters may be necessary to characterize any suspected contamination.

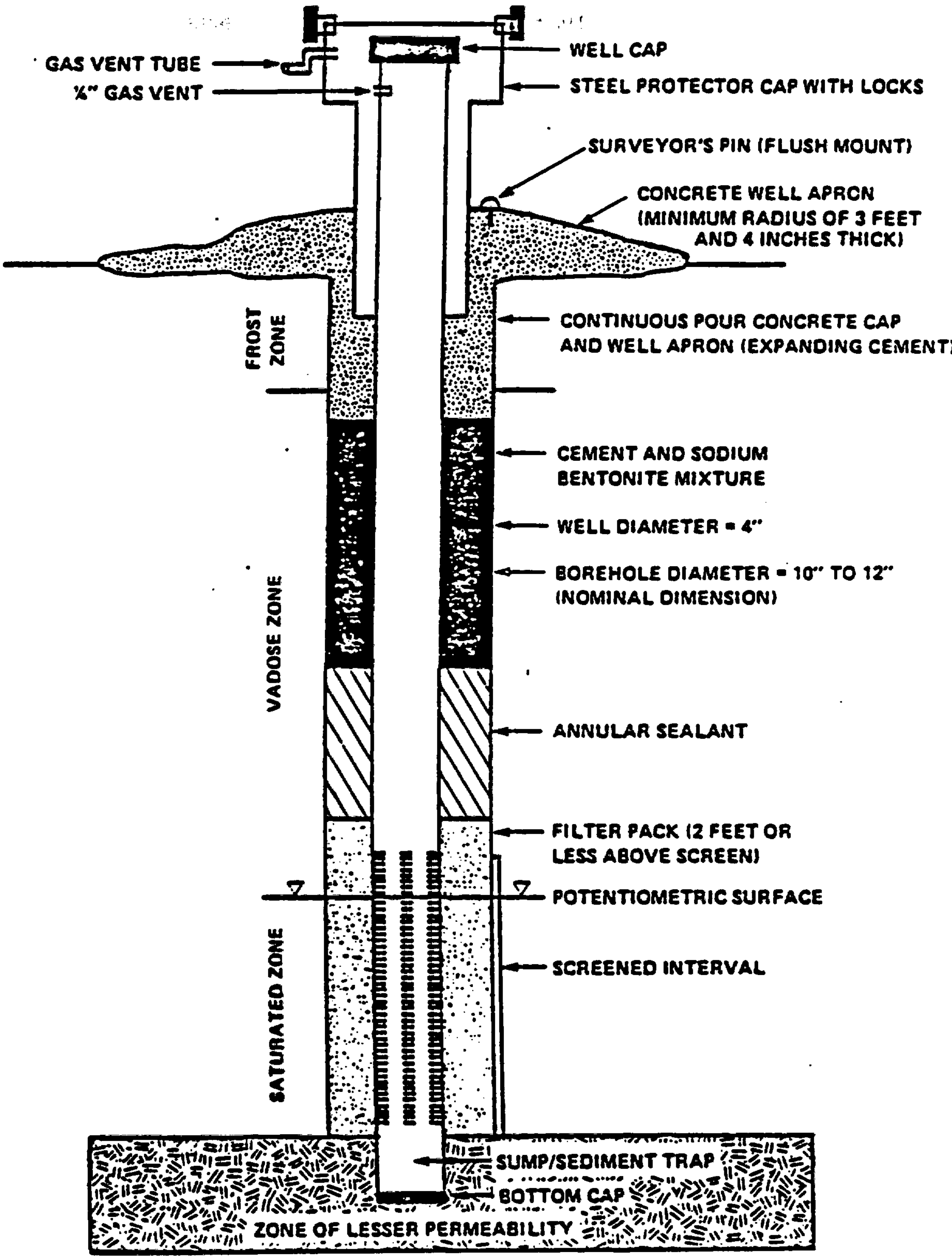

Figure 3: General Monitoring Well Cross Section

The site characterization program should include sufficient sampling and analysis of groundwater samples collected upgradient from the site to develop a representative characterization of background groundwater quality. Background groundwater quality should not exhibit any influence from contaminants released by the site and should be representative of the quality of groundwater that would exist if the site had not been contaminated. The SCR should also assess any temporal or spatial variations in background groundwater quality. If sources of contamination other than the facility are present, the potential impact of such sources should be evaluated to determine the degree of groundwater contamination caused by these sources.

4.6 Structures and Equipment

The contaminated structures include surfaces of floors, walls, or ceilings of buildings. Roofs and roof drains, especially those near airborne effluent release points, may also represent sources of radiological contamination. Most structures have concrete floors covered with paint or tiles and surfaces are commonly made of wood with plaster boards, bricks, concrete, or metal. In some cases, surfaces are covered by several layers of paint that may obscure any previous spills or contamination. The joints between walls, or between walls and floors, pipes, or conduit runs are common places of contamination. Liquid lines buried in walls, floors, or the ground represent special concern because of potential contamination from seepage.

Contaminated equipment may include hot cells, piping, ducting, fume hoods, hand tools, and supplies. Knowing the history of the facility and its operation may help the characterization process, especially when potentially contaminated surfaces are inaccessible for radiological measurements without extensive effort.

The number and type of radiological measurements depend on the radionuclides present, the level of activity, and the criteria or guidelines used for decontamination and decommissioning of structures and equipment. The interim NRC guidelines for decontamination and decommissioning of surfaces and equipment are included in NRC Regulatory Guide 1.86 (NRC, 1974); NRC Policy and Guidance Directive FC-83-20 (NRC, 1983a and 1987); and NRC NUREG/CR-5849 (NRC, 1992d).

The SCR should characterize the extent of contamination in (or on) structures and equipment in terms of maximum and average surface activities (fixed and removable) in disintegrations per minute per 100 cm^2 and exposure rates. In addition, the characterization program also should determine radionuclide concentrations on a volume basis where the contamination is present within structures and equipment (e.g., activation products). NUREG/CR-5849 provides generic guidance on acceptable approaches, methodologies, and analyses in support of radiological characterization of structures and equipment. It should be indicated that the site characterization will, in most cases, not require the same level of detail as is prescribed in the NUREG/CR-5849. The draft "*Multiagency Manual for Environmental Radiological Surveys*" (May 1994), which has been developed collaboratively by the four Federal agencies, the NRC, the EPA, the DOE, and the DOD (unpublished) provides additional comprehensive guidance on radiological survey procedures, techniques, and methods, and on survey planning, evaluation, and documentation for surface contamination.

4.7 Air

Air sampling, monitoring, and analysis may be necessary for a few sites where radioactive material may reasonably become airborne from decommissioning practices or during remediation or waste handling. In fact, these activities may be conducted as part of both the operational and the characterization programs. The most common examples of air contamination are sites where dust loading of contaminated material or release of gaseous radioactive material (e.g., radon emanation) will be a potential inhalation exposure pathway. For example, dust loading and radon releases from site construction activities may be significant release mechanisms for radionuclides, such as ^{238}U and ^{232}Th and their associated decay products. Other sites may also involve gaseous releases, such as ^{3}H and ^{14}C.

At those sites where potential releases of radionuclides via the airborne pathway may be significant, the SCR should establish a representative baseline concentration for radionuclides under pre-existing background conditions. This can be accomplished by constructing upwind air sampling stations and conducting offsite measurements in unaffected areas. The main parameters to be characterized to establish baseline conditions for air quality include: contaminant type and concentrations. The SCR should also identify the regional air quality classification, air quality control region, and pertinent air quality guideline levels. Previous and/or existing sources of airborne radionuclides and the geographic designation of these sources should also be identified.

Air sampling and monitoring should be carried out during site characterization (1) at representative upwind locations that are not affected by site activities; (2) near sources of potential contamination, including evaporation ponds, incinerators, and disposal cells and trenches; (3) adjacent to the downwind site boundary; and (4) offsite in downwind direction to determine whether existing airborne releases significantly affect downwind air quality. The location of air sampling stations should be selected to enable measurements of any contaminated material (soil/dust) that might become airborne across the contaminated site. The sampling locations should be selected based on consideration of site-specific meteorological data (e.g., wind direction and speed; stability class) and critical-group locations. The number of sampling stations will depend on the potential for significant offsite contamination based on site history and assessment of planned decommissioning actions, level and nature of site contamination, site area, and prevailing meteorological conditions.

Air samples should generally be analyzed to determine total alpha particle activity and total beta/gamma spectrum activity. Key radionuclides should also be determined, if necessary, to ensure adequate public and worker protection during conduct of decommissioning actions. The sampling results should be reported in terms of concentrations in μCi/ml (or Bq/ml), along with error estimates and lower limits of detection for each sampling station. Sampling results should be compared with the acceptable airborne concentrations listed in Appendix B to 10 CFR Part 20. For large decommissioning projects, the airborne sampling program should be integrated with an environmental sampling, which may include environmental thermoluminescence detectors (TLDs) and routine representative sampling and analysis of offsite water, soil, sediment, vegetation, and wildlife. For more detailed guidance on air effluent releases and environmental monitoring consult the following NRC guidance documents: NUREG-1388 (NRC, 1989c); NUREG-1383 (NRC, 1989b); NUREG/CR-3332 (NRC, 1983b); Regulatory Guide 1.111 (NRC, 1977); Regulatory Guide 4.15 (NRC, 1979a); and EPA/540/0-89/002 (EPA, 1989c).

5. PHYSICAL CHARACTERISTICS OF SITE

5.1 Surface Features

This section of the SCR should describe the present topography of the site and immediate vicinity using topographic maps of appropriate scale and contour intervals. The maps should also depict significant surface features such as depressions, buildings, utilities, wet-lands, rivers, valleys, creeks, ditches, landfills, diversion channels, and drainage system. Topographic maps should generally be at the 1:200 scale or larger. Other scales may also be appropriate if they are large enough to clearly depict the major surface features of the site relative to the decommissioning action. The contour interval should be selected on a site-specific basis considering the relief and grade of the site, but should generally be no greater than 2 to 5 feet. The topographic maps should use conventional nomenclature and symbols (e.g., U.S.G.S. topographic map symbols). Any departures from standard symbols should be clearly delineated in the legend for the map. All maps should include a north arrow, graphical scale, date, reference datum, and unique identifier (e.g., project and map numbers).

5.2 Meteorology and Climatology

The SCR should provide baseline information describing normal and extreme weather conditions at the site. Such information may be necessary to assess the water budget for the site (e.g., comparison of annual precipitation to runoff, infiltration, and evapotranspiration) and evaluate impacts resulting from long-term releases of radionuclides via groundwater or surface water pathways. The information is also needed to evaluate short-term transport of contamination, which may occur prior to and during site characterization and decommissioning (e.g., severe flooding during excavation of contaminated materials). Examples of significant meteorological and climatological parameters and data to be reported include:

- Speed, directions, and variability of winds (presented as a wind-rose diagram and the Pasquill atmospheric stability category);
- Amount, type, and distribution of annual precipitation;
- Estimates of pan evaporation and evapotranspiration (if available); and
- Records of severe weather conditions such as tornadoes, hurricanes, drought, and flooding, that may affect the stability of the contaminated material before, during, and after decommissioning.

5.3 Surface Water Hydrology

The SCR should evaluate surface water at and near the site and the effects of surface water processes on transport of contaminants. The site characterization program should address both general characteristics of surface water near the site, as well as site-specific field measurements to quantify the flow system. Such information includes, but is not limited to, the following:

1. Surface water hydrologic systems (names and types), their locations, qualities (e.g., macrochemistry), and quantities (e.g., flow rate and/or area and volume). The systems may include natural surface water bodies such as lakes, ponds, rivers, streams and coastal areas onsite or in the immediate vicinity of the site. They may also include man-made systems such as dams, channels, and diversion ditches. Proximity and transport between surface water systems and site contamination should be discussed.

2. Historic data on peak discharge rates and water levels. Stage/discharge relationships and recurrence intervals of flooding events for adjoining water bodies may also be needed. These may include estimates of stages, flow rates, and flow velocities for severe flooding events, such as the Probable Maximum Flood and 100-year flood. Such estimates may especially be necessary at sites where large inventories of long-lived radioactive material will be disposed to ensure that the disposal method provides reasonable assurance that the waste will remain sufficiently isolated from the human environment for long time periods (e.g., 1000 years).

3. Locations, areas, and dimensions of wet-lands, 100-year floodplains, and watershed divides relative to the site. Surface erosion and potential contaminant transport associated with such surface processes should also be addressed.

4. Current inventory of surface water uses within approximately 10

kilometers of the site. Relevant information on types of water uses, rates of withdrawal, sources of water supply, and water quality should be provided. Identification of the nearest down-gradient surface water and the nearest municipal intake should also be included.

5. Estimated potential for contamination of surface water bodies above applicable and relevant water quality criteria. The potential for significant infiltration and transport should be evaluated using analytical or numerical techniques for representative models of the hydrologic system [e.g., NRC (1990b and 1990c); Celia et. al. (1990); Gee and Hillel (1987); and Shulz et. al (1988)]. At some sites, the potential for significant transport is so minimal, that qualitative analysis of potential surface water transport will suffice. At other sites, particularly where decommissioning entails stabilization of large inventories of radioactive material onsite, more sophisticated and quantitative analysis should be conducted (as given in the references mentioned above) to assess potential transported concentrations in downgradient surface water bodies. These concentrations should then be compared with relevant surface water quality criteria assuming annual mean flow conditions, stages, or levels. The assessment does not need to estimate concentrations in downgradient waters under extreme flow conditions (e.g., 100-year flood).

5.4 Geology

The SCR should describe site geology sufficiently to support assessments of the long-term stability of the site (particularly if onsite disposal is a preferred option), groundwater transport of contaminants, and selection of representative locations to collect background soil and water samples. Typically, geologic site information is presented in two categories: reconnaissance information on the region surrounding the site, and site-specific geologic characteristics.

5.4.1 Regional Geology

Reconnaissance information on the geology of the region surrounding the site is often available from State geological surveys, U.S.G.S., or local colleges or universities. This subsection of the SCR should include general geologic information about the region surrounding the site and provide a clear link to the structure and geology of the site. Such information should be presented in a concise fashion so that it will represent background information for the more detailed site specific geologic characteristics. The SCR should use an appropriate combination of text, charts, and maps to convey the regional geologic information in an efficient and effective manner. Specifically, this section should include, as a minimum,:

- A general stratigraphic chart for the area depicting major formations and their thicknesses and characteristics (include units to at least 500 feet beneath the site);

- A geologic map, of an appropriate scale, depicting the bedrock geology (formations and structures) that covers an area including the site to at least 5 km distant from the site boundaries; and

- A geologic cross-section, of appropriate vertical exaggeration (no greater than 10x), that is keyed to the geologic map and depicts the principal structures and geologic formations for at least 300 feet beneath the site.

Stratigraphic columns, maps, cross sections, photogeologic maps, and aerial photographs (if available) should be provided at appropriate scales and in a manner that adheres to national topographic and geologic mapping conventions (e.g., those conventions established by the USGS).

In addition, the summary of the regional geology should include the following information:

(a) Geomorphology: information on physiographic province that contains the site and any prominent topographic features within 10-20 km from the site. Emphasis should be placed on identification of geomorphic processes that may affect long-term stability of the site, particularly fluvial landforms such as floodplains (100 years and less), stream terraces, basins, and other landforms (e.g., dunes, fault scarps, rock falls) and the dynamic processes that shape them, such as mass wasting, sheet wash and gully erosion, and subsidence.

(b) Stratigraphy and Lithology: this includes regional stratigraphic units and regional bedrock formations. General information should include the distribution, thicknesses, relative sequence and age, and lithologic descriptions of each significant formation (generally down to 500 feet beneath the site). Special attention should be given to stratigraphic contacts, bedding surfaces, unconformities as well as significant facies changes.

(c) Structure and Tectonics: significant geologic structures and their association with any active (Holocene) tectonism. Such features may include, but not be limited to, faults, folds, joints, cleavage, and major fractures. Primary structures should be depicted on the regional geologic map (scale 1:24000 or greater) along with indications of the dip and strike of major geologic units. The regional structural geology and tectonic description should encompass an area within 20 - 50 km from the site. The current tectonic stability of the region and its potential for active tectonism along with historic records of seismic activity should be included.

The description should also include evaluation of historic seismicity in the region and identification of any seismic source zones and paleo-liquefaction features. Such information should also include assessment of peak horizontal and vertical ground accelerations associated with the "Maximum Credible Earthquake" (MCE), if decommissioning includes stabilization of radioactive material onsite.

5.4.2 Site Specific Geology

The SCR should describe the site-specific geologic characteristics in a similar manner to the regional geologic description. The site-specific description, however, should focus on details of site geology and its effect on long-term release and transport of radiological contaminants and stability of residual material. The following site-specific geologic information should be included in the SCR:

(a) Geomorphology: height above modern base level, on-site relief, surface gradient, small-scale geomorphic features and surficial topography, soil weathering profile and associated surface deposits, local drainage basins and their relationships to regional drainage, and descriptions of channels at the site in terms of gradient, morphology, pattern and recurrence of flow events. Other significant site-specific geomorphic processes that could influence long-term containment or release of contaminants should be also addressed (e.g., mass wasting[2], solifluction[3], subsidence). The description of fluvial geomorphology should be linked to the hydrologic characterization in Section 5.3.

(b) Stratigraphy and Lithology: descriptions of surface and subsurface geologic units that have been or potentially could be affected by transport of radiological contaminants from the site or that could affect the stability of any significant quantities of radioactive material disposed of at the site. Descriptions should include depth, thickness, and characteristics of the stratigraphic units based on site borehole data and projections from surface data or other onsite or regional studies. Vertical and lateral variations

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[2] *Mass wasting is the downslope movement of masses of bedrock or soil and rock debris under the influence of gravity. This dynamic process is responsible for shaping of landforms in areas of particularly weak rock formation or clayey soils.*

[3] *Solifluction is the slow creeping of saturated fragmented material (as soil) down a slope. This process usually occurs in regions of perennial frost.*

of the stratigraphic column should be analyzed. Bedrock/sediment interface and its association with depositional and/or erosional processes should be explained. Borings, trenches and outcrops should be shown on a geologic map and geologic cross sections. Maps and cross-sections should include all borings and trench locations used to develop the maps and sections. A stratigraphic log should be presented for each borehole and trench used to characterize the detailed variation of site stratigraphic features. A sample log is presented in Figure 4.

The site geologic description should also present detailed information on the lithologic characteristics of surface and subsurface deposits and the bedrock. The lithologic information includes mineralogy (special emphasis on presence of evaporitic salts and clay minerals) and other characteristics (e.g., grain size, fabrics, texture, organic content, and type of cementitious materials) that may affect the mobility and release of contaminants in groundwater. Lithologic composition and development of local structural features such as foliation and fracturing should be also be given special consideration to the extent that it may enhance or affect groundwater transport of contaminants.

The number of boreholes, trenches, or excavations necessary to characterize the site geology will depend on the site area and stratigraphic and structural complexity of the site. In general, the number of penetrations and excavations necessary to characterize site geology will be less than the number needed to assess the extent and nature of soil and groundwater contamination.

Figure 4: A Sample Well Log Showing Details of Startigraphic Features

HOLE/WELL NO: DATE STARTED: ATE FINISHED: DRILLER: INSPECTOR:	WELL LOG	SHEET OF: SURFACE ELEVATION: GROUNDWATER DEPTH: MEASUREMENT DATE:
PROJECT: JOB NUMBER:		LOCATION: Locale:

DEPTH IN FEET	INCHES DRIVEN / RECOVERED	SAMPLE TYPE-NO.	BLOWS ON SAMPLER 0 / 6	6 / 12	12 / 18	18 / 24	MOISTURE	UNIT	LITHOLOGY	DESCRIPTION / NOTES
								FILL		augered to 2.0 ft.. black SLAG.
	24/10			4	5	7		CL		reddish-brown to greenish-brown CLAY, mottled, medium stiff, hi-plasticity. (CL)
5	24/15			6	6	7		CL		
	24/17			5	5	8		CL		
	24/20			5	6	9		CL		reddish-brown sandy silty CLAY. (CL)
10	24/14			6	9	9		CL / SW/SM		dry, reddish-brown silty CLAY. (CL) dry, reddish-brown silty clayey SAND to reddish-brown sandy silty CLAY. (SW/SM)
	24/18			6	8	9		SW/SM		
15	24/17			12	12	10		SW/SM		Grades to...reddish-brown silty clayey SAND, banded. (SW/SM)
	24/14			10	10	15		SW		dark reddish-brown SAND. (SW)
20	24/18			12	14	15		SW		
	24/18			14	20	24		SW		Grades to...damp to wet.
	24/16			8	5	6		SW		Grades to...saturated.
25	24/17			8	10	12		SW		Grades to...greenish-brown.
								SW		augered to 30.0 ft.
30	24/24			12	14	12		CL		grey silty CLAY, very stiff, hi-plasticity. (CL)
35										

CLASSIFICATION:

METHOD OF SAMPLING: ASTM-D1586-84

(c) Site Structural Features and Geologic Stability: identification of discontinuities, such as large bedding planes, joints, and fracture systems, that could influence contaminant transport through the underlying bedrock. Other macrostructural features such as shear zones, folds, faults, and igneous intrusions (e.g., dikes), if present, should also be described. For each major discontinuity or set of discontinuities, the description should assess orientation, persistence, aperture, and other characteristics to the extent that they may affect groundwater transport of contaminants or stability of radioactive materials onsite.

(d) Geologic stability: estimates of the long-term stability of the site. Site stability should be evaluated by estimating the maximum ground motion that can reasonably be anticipated at the site based on records of seismic events, estimates of the MCE for the site, and considering other geologic indications of active processes during the Holocene period that could significantly affect site stability.

5.5 Demography and Land Use

5.5.1 Demography

Population data on the site and its surroundings are necessary for assessing the potential health and safety and socioeconomic impacts of radiologically contamination. The demographic data to be provided include:

(a) Residence Inventory: this inventory should identify the location and number of residents within a 2-km radius from the site boundary. The residential units should be shown on a map with an appropriate scale. Existing (e.g., tax assessment) maps and aerial photographs can also be used for this purpose. Any sensitive populations (e.g., medical institutions, day care facilities, nursing homes, prisons) should be identified within the 2-km radius.

(b) Transient Population: the assessment should identify any periodic (e.g., daily) or seasonal changes in baseline population within the 2-km radius. Such changes may be caused by transient residency associated with resorts or vacation homes or to influxes associated with work, education, health care, day care, and other similar activities.

5.5.2 Land Use

This section of the SCR should evaluate the type of land uses at the site and the surrounding vicinity as the basis for assessing potential impacts on public health and safety from radiological releases from the contaminated site. Land use information will be used in assessing the impacts of radiological releases from the site as well as potential onsite exposure due to decommissioning. Historic and current records of land uses may be obtained from U.S.G.S or from State, regional, municipal, or other planning agencies. The U.S Department of Interior and the U.S Department of Agriculture can also provide relevant information on existing and future land use. The type of land uses should be categorized, in a broad manner, in one or more of the following types: residential, industrial, agricultural, and special use.

For agricultural uses, the assessment should identify specific uses of the land for grazing, dairy farming, crop production, or livestock grazing. The SCR should also provide information on any endangered species in the area that could be affected by contamination or by the decommissioning activities. Any special land uses in the vicinity of the site should be described. Examples of special uses include: national parks, wildlife refuges, and military reservations.

5.6 Hydrogeology

The hydrogeologic characterization should describe the hydrogeologic environment in sufficient detail to quantify the transport mechanisms for radiological constituents in support of dose pathway assessment. If the preferred decommissioning approach includes onsite stabilization of contaminated materials, the hydrogeologic characterization may also need to consider the effect of elevated groundwater levels on site stability and long-term transport of contaminants via leaching and groundwater transport.

The level of hydrogeologic characterization should be proportional to the anticipated hazards arising from groundwater contamination or elevated groundwater levels. More hydrogeologic characterization will be needed at sites with existing groundwater contamination to support groundwater remediation decisions, planning for groundwater corrective actions, characterization of the extent and migration of the contamination, as well as long-term human exposure assessments. The relative distance of the affected human and environmental populations and water users should also be considered in defining the scope and extent of characterization needs. Hydrogeologic characterization should generally include the information in the following sections.

5.6.1 Identification and Characterization of Hydrogeologic Units

Information should be presented on all potentially affected hydrogeologic units, including soils, unsaturated units, and saturated units. For each unit, specific data should be provided on its geometry, lateral extent, thickness (and variation), recharge and discharge zones, and flow characteristics (e.g., porous media flow vs. fracture flow).

5.6.1.1 Soil Characterization

Measurements of primary soil characteristics are required to evaluate extent of contaminant transport via the soil to groundwater, surface water, and plants. Soil characterization is also required for dose assessment and for determining the potential effectiveness of remediation alternatives. The characterization should define particle size distribution and soil class based on particle size and compositional analysis (e.g., clay, silt, sand (fine, medium and coarse), gravel (fine and coarse), and cobbles). The analysis should also describe primary soil characteristics, such as bulk density, soil pH, texture, stratigraphy (e.g., horizons or macrostructure of the soil and vadose zone), hydraulic conductivity (saturated and unsaturated (as a function of soil moisture content)), water retention (soil water characteristic curves), porosity (total and effective). Other soil parameters could also be necessary depending on site conditions, including organic carbon content, ion exchange capacity, soil structure, and redox couple ratios of waste/soil system. Soil characteristics should be grouped into the following four categories:

1. Mass transport characteristics: soil texture, unsaturated hydraulic conductivity, dispersivity, moisture content versus soil moisture tension, bulk density, porosity (total and effective), infiltration rate, stratigraphy, and other associated parameters.

2. Soil reaction characteristics: distribution coefficients (K_d), cation exchange capacity (CEC), Eh[4], pH[5], soil biota, soil nutrient content, contaminant abiotic/biological degradation rates, soil mineralogy, and contaminant properties.

3. Soil contaminant properties: water solubility, dielectric constant, diffusion coefficient, distribution coefficient (K_d), total organic carbon content, octanol-water partition coefficient (K_{oc}), molecular weight, vapor pressure, density, and aqueous solution chemistry.

4. Soil engineering characteristics and properties: trafficability, erodability, bulk modulus, plasticity, depth and total volume of contaminated soil, and bearing capacity.

5.6.1.2 Vadose Zone Characteristics

The vadose zone extends from the lower boundary of the soil (root zone) down to the water table (saturated zone). Water flow in the vadose zone is

[4] *The Eh value is the theoretical equilibrium electrical potential of a redox couple.*

[5] *The pH is a measure of the degree of acidity or alkalinity.*

essentially downward; it depends, however, on several physical and hydrologic characteristics of the stratigraphic units comprising the zone. The following parameters may be required for assessment of contaminant transport in the vadose zone: volumetric water content, degree of water saturation, particle density, bulk density, matric potential, moisture content, relative permeability, water diffusivity, and other source/sink terms.

The extent of vadose zone characterization depends on the degree and extent of contamination and significance of transport pathways and exposure routes. At sites where the vadose zone is extremely thin or the licensee or responsible party does not wish to take credit for contaminant attenuation in the vadose zone, only minimal information may be necessary to characterize the vadose zone (e.g., soil engineering characteristics and depth to the water table). The volumetric flux of pore water and the long-term movement of water through the unsaturated zone will be the result of net infiltration. Infiltration rate may be estimated using either simple algebraic balance models, or modeling flow through the zone along with *in-situ* measurements of matric potential or suction versus moisture content, hydraulic heads, and unsaturated hydraulic conductivities of soil samples.

5.6.1.3 Saturated Zone Characteristics

The assessment should also determine representative characteristics for saturated hydrogeologic units. Although the assessment should include all aquifers, confining units, and aquitards[6] along significant transport paths, the assessment should primarily focus on the characteristics of the uppermost aquifer beneath the contaminated site. The uppermost aquifer means the geologic formation nearest the natural ground surface that is an aquifer, as well as low aquifers that are hydraulically and significantly connected with this aquifer beneath the site or in its immediate vicinity. Hydraulic properties of potentially affected saturated units should be described in terms of hydraulic conductivities, storage characteristics, effective porosities and dispersivities, and recharge/discharge locations and rates. Hydraulic characteristics also include: distribution of hydraulic heads, leakance rates[7] to other aquifers through confining units, and the locations and rates of internal sources and sinks within the aquifer.

Hydrogeologic site characterization should also describe hydraulic gradients, groundwater flow directions, and groundwater velocities for each hydrogeologic unit anticipated to be affected by residual contamination. The SCR should

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[6] *The aquitard is a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a storage unit for groundwater.*

[7] *The leakance rate is the ratio of the vertical hydraulic conductivity and the thickness of the confining beds.*

present the hydraulic head data in map form depicting control points, head measurements, flow directions, and boundary conditions. At sites with appreciable vertical gradients, the SCR should also include appropriate hydrogeologic cross-sections that illustrate the variation of head with depth and as a function of hydrogeologic unit and boundary conditions. Spatial and temporal distribution and isotropy of these properties should also be addressed to the extent that they may significantly affect the transport of radiological constituents or associated non-radiological constituents. The properties to be analyzed should be based on a combination of field data and a demonstrably representative hydrogeologic system.

The assessment should also describe representative transport characteristics of saturated hydrogeologic units. This subsection should describe the water quality for all potentially affected hydrogeologic units. The hydrochemistry should be described in terms of concentrations of major and minor inorganic, organic, and radiological constituents. Other hydrochemical parameters that should be determined include pH, redox potential, temperature, total dissolved solids (TDS), and specific conductance. These parameters help demonstrate the representativeness of water quality samples as well as provide a basis for generally classifying the usability of the groundwater.

Selected non-radiological characteristics and parameters have been included in the list of hydrochemical information needs. Such information may be necessary to demonstrate compliance with NRC requirements by assessing the effect of the non-radiological constituents on the mobility and transport of radiological constituents. In addition, other regulatory agencies may require these parameters and values to be characterized to satisfy requirements promulgated under statutes other than the Atomic Energy Act. Their inclusion in this guidance is intended to assist licensees and responsible parties in conducting integrated site characterization programs that may address regulatory requirements beyond those of just NRC. Such non-radiological information is also necessary to support environmental assessments in accordance with 10 CFR Part 51 and the National Environmental Policy Act.

Water quality data should be accompanied with supporting hydrochemical data that will be used to demonstrate the reliability of analytical data. Examples of useful information in this regard are ion balances, comparison of the sum of dissolved solute concentrations with measured TDS values, and geochemical/hydrochemical diagrams like Piper and Stiff diagrams. Each analysis should generally exhibit a balance of cations and anions within +/- 5 percent, unless the analysis is accompanied by a justification for significant departure from neutral conditions. Similarly, the sum of all major and minor ions determined in each water quality analysis should be within 10 percent of the measured TDS value.

Geochemical conditions at the site and their association with groundwater and contaminants should also be described. Specifically, geochemical conditions that enhance or retard contaminant transport should be given special consideration. Geochemical data should include information on solid composition, buffering capacity, redox potential, sorption (represented as a range of distribution coefficients for each radiological constituent), and other relevant geochemical data. In general, licensees or responsible parties may estimate K_ds through laboratory column or batch sorption measurements [e.g., ASTM methods D4319 (ASTM, 1983); D4646 (ASTM, 1987); and D4874 (ASTM, 1989)] or by using a conservative value to represent the K_d from available literature references [e.g., Sheppard and Thibault (1990) and NRC NUREG/CR-5512 (NRC, 1992b)]. If necessary, licensees (or responsible parties) may use appropriate geochemical codes to understand and quantify geochemical mechanisms that significantly affect transport of radiological and non-radiological contaminants and their potential fate [e.g., MINTEQ (EPA, 1984); EQ3/6 (Daveler and Woolery, 1992)].

5.6.2 Groundwater Flow and Transport Models

Groundwater flow system(s) at the site should be represented using conceptual and computational models that are demonstrably conservative, reliable, and representative of the actual flow conditions. The role of groundwater modeling and modeling needs in support of remedial and decommissioning decision making at sites contaminated with radioactive materials is provided in EPA document "*Environmental Pathway Models - Groundwater Modeling In Support of Remedial Decision-Making At Sites Contaminated with Radioactive Material*" [EPA402-R-93-009 (EPA, 1993a)] and other documents (e.g., EPA, 1990a, and 1992d). The generic site parameters anticipated to be needed for groundwater pathway models, to be employed for decommissioning sites, are given in Table 1. The degree of sophistication of these models (e.g., one-, two-, or three-dimensional flow models) will depend on degree of site complexity and level and extent of radiological contamination. The mathematical models can be either analytical or numerical.

Table 1. Common Site-Specific Input Parameters for Groundwater Transport Models

Zone or Unit	Site Parameter
Cover	Thickness Density Erosion rate
Contaminated Zone	Area Thickness Length parallel to aquifer Time since contaminants placed Density Erosion rate Total porosity Effective porosity Hydraulic conductivity Evapotranspiration coefficient Annual precipitation Irrigation rate Irrigation mode Run-off coefficient Distribution coefficient Contaminant concentration Leach rate
Uncontaminated-Unsaturated Zone	Thickness Density Total porosity Effective porosity Hydraulic conductivity Distribution coefficient
Saturated Zone	Density Total porosity Effective porosity Hydraulic conductivity Hydraulic gradient Water table drop rate Well pump intake depth Average individual use of groundwater Cross-sectional area of plume

Models users should be careful not to misuse the computer models, as described in the National Research Council's publication entitled, "*Ground Water Models: Scientific and Regulatory Applications,*" National Academy Press, 1990. Additional useful guidance and references on groundwater models, modeling, and model-validation are: Mercer and Faust (1981); U.S.G.S (1978 and 1988); NRC (1991b,c and 1991d); EPA (1992c and 1993a); Tsang (1991); Konikow and Bredehoeft (1992); and Zheng (1990). Under certain conditions, special consideration may be given to fracture and/or vertical flow. The general guidance on dose assessment models presented in Section 6 of this position is also applicable to the development, execution, and use of groundwater transport models.

The groundwater transport codes should be selected based on appropriateness of the conceptual models used in these codes and its consistency with the available hydrogeologic data and the actual groundwater system of the site. The SCR should describe these models and provide a justification for the selection of the code(s) that were used as the basis for the computational models used to project contaminant transport under long-ter site conditions. These models should be accompanied by appropriate hydrogeologic cross-sections and maps depicting the various flow directions and boundary conditions that significantly affect groundwater flow and transport at the site.

5.6.3 Hydrogeologic Characterization Methods and Monitoring Practices and Procedures

This section should include a description of all hydrogeologic site characterization activities, methods, and monitoring installations sufficient to demonstrate that the site characterization methods and devices provided data that are representative of site conditions. The SCR should describe the monitoring practices, procedures, and quality assurance programs used to collect water quality and hydraulic data. Monitoring well descriptions, for example, should include location, elevation, screened interval(s), depth, construction and completion details, and the hydrologic units monitored. Figure 3 provides an example of an acceptable monitoring well diagram. Aquifer test descriptions should include testing configuration, test results, and a discussion of the assumption., analytical techniques, test procedures, pre-testing baseline conditions, limitations, errors in measurements and final results. The SCR's description of the water quality sampling and analysis program should include or reference the procedures for sampling, preserving, storing, and analyzing the samples including quality assurance/quality control (QA/QC) protocols implemented. All methods used should be consistent with current standard methods and practices (e.g., ASTM, U.S.G.S, EPA, NIST, and ANSI/ASME). Licensees and responsible parties are encouraged to consult the references listed in Section 7 of the BTP for guidance on acceptable methods for sampling and analyzing water quality samples [e.g., Korte and Ealey (1983); Korte and Kearl (1984); DOE (1988 and 1993); ANSI/ASME (1986); EPA (1977a, 1985, 1986, 1987b, 1991) and NRC (1979a, 1989a and 1989b)]. Any deviations from standard methods should be appropriately justified.

5.7 Geotechnical Engineering

Although some of the previously described site characterization efforts for geology and hydrogeology would also be applicable to geotechnical engineering considerations (e.g., the completion of subsurface investigations to establish geologic information and profiles), this section of the BTP is intended to address the additional aspects in geotechnical engineering that would not typically be encompassed by the other disciplines. These additional site characterization efforts may be needed for assessment of long-term onsite stabilization or storage of radioactive material. The geotechnical characterization data will be used to support the following activities:

1. The development and interpretation of site data, including potential sources of fill materials to establish detailed cross-section displaying factual soil and rock layering and groundwater conditions that would be used in engineering design studies;

2. The evaluation of site data developed from the results of field and laboratory testing to establish engineering properties of site materials for eventual consideration in stabilization of radioactive wastes; and

3. The determination of the initial suitability of the site's soils and rock to support the proposed decommissioning remediation plan.

This effort to address the suitability of the site's soils is an initial assessment, which determines if the identified and available site soils which were uncovered in the site characterization investigation, can be further considered in the conceptual remediation plan. The final determination on suitability would not be made until the completion of the dose assessment and design studies for the remediation plan.

5.7.1 Soil Layering and Groundwater Conditions

The description of the subsurface investigations and the recording of the investigation results need to be clear and thorough to permit an evaluation of the geotechnical parameters that would be needed for the engineering analysis and design. Guidance for conducting site investigation can be found in NRC Regulatory Guide 1.132, "*Site Investigation for Foundations of Nuclear Power Plants*," (NRC, 1979b). This guide contains the type of information to be developed regarding geotechnical investigation, the essential information to be recorded on boring logs, measurements of groundwater conditions, identification of the standards and procedures on the methods of subsurface exploration, spacing and depths of explorations, and sampling procedures. Although Regulatory Guide 1.132 was initially developed for geotechnical investigations at nuclear power facilities, much of the guidance is generic and presents accepted practice in subsurface investigations. This guidance has direct application in decommissioning projects when experience and reasonable judgment are exercised to tailor the subsurface investigations to the level of complexity and degree of contamination associated with the sites to be decommissioned.

Typically, for contaminated sites requiring remediation, the results of the subsurface investigations would be transposed onto engineering profiles and cross-sections that would be selected at strategic locations to address design conditions (e.g., to ultimately set drainage features or excavation slopes and limits for the contaminated materials to be removed). The engineering profiles and sections would typically be drawn with equal vertical and horizontal scales with the features displayed at a scale not smaller than 1" = 20 feet.

Experienced judgement is needed in the selection of the cross-section location and in the number of sectional views in order to reasonably represent the soil and rock layering and groundwater conditions. The extent of the subsurface investigations that are to be completed is dependent on the extent of the contamination and needs to be sufficient to permit characterization with a reasonable degree of confidence. After verifying the accuracy of the developed sectional views that would include checking for agreement with the actual field records (e.g., boring logs), considerable judgment is typically required to ultimately establish the outline of the affected structures and utilities, soil layering and seepage conditions along the profile between the widely spaced explorations. It is helpful when developing the soil layering and groundwater sectional views to have a basic understanding of the special importance of the sections (e.g., to delineate weak or unstable zones, or to set limits for removing contaminated materials) so that careful attention can be focussed on the relevant data that were recorded in the site investigations.

5.7.2. Field and Laboratory Testing

A laboratory and field testing program is normally planned and performed as a follow-up to the subsurface investigations to determine soil and rock properties and characteristics which will ultimately be needed for engineering analysis and design (e.g., in the assessment of slope stability, liquefaction resistance, settlement, or cover integrity). The testing program to establish these properties needs to be coordinated and be an integral part of the site characterization effort because, if appropriate samples are not covered during the site characterization phase, the test results will not readily be available when needed in the later design stages. Long delays in completing the design of the remediation plan are likely because remobilization of the site investigation equipment and field personnel would need to take place to sample and test the controlling site materials.

Guidance for conducting testing programs is provided in NRC's Regulatory Guide 1.138, "*Laboratory Investigation of Soils for Engineering Analysis and Design of Nuclear Power Plants,*" (NRC, 1978). This guidance includes recommendations for:

1. Developing a testing program that is flexible and tailored to the needs of each site,

2. Handling and storing samples,

3. Selecting and preparing test specimens,

4. Establishing test procedures, and

5. Documenting the test results.

Appendix B to Regulatory Guide 1.138 provides useful information covering a wide variety of tests and includes guidance on the preferred test method or standard, identifies typical engineering properties or parameters to be determined with special remarks concerning equipment requirements. Offering Regulatory Guide 1.138 as guidance is intended to help in deciding what testing and test standards can be considered during site characterization. It is not intended to imply that all the tests listed in the guide are necessary. Applying the guidance requires judgement that is project-specific and dependent on the complexity of the site and the scope of the proposed remediation.

The SCR should describe the laboratory and field testing programs in sufficient detail to permit an evaluation of the scope and techniques of the testing programs to establish the engineering properties. Drawings in the SCR should clearly relate the location of the completed explorations to the testing results. The testing results on the site soils and rocks should be presented in summary form (e.g., tabular and/or graphical) to permit a prompt assessment of the conservatism and reasonableness of the results.

5.7.3 Suitability of Site Soils

Investigations in site characterization effort should not focus only on establishing the extent of the contaminated materials, but should also be sufficiently flexible to explore potential site and area soils that may be used in site remediation.

In the course of completing site characterization work for decommissioning sites, information may be developed that could indicate that certain site soils have engineering properties that are desirable for use in various potential remediation plans. Examples of this finding might be the discovery of clean granular soils for possible placement as filter or drainage soil, or the locating of a fine-grained low-permeability site soil that would make an excellent cover material by minimizing infiltration. If these conditions are discovered in site characterization efforts, it is important that the exploration and testing programs be sufficiently flexible to adjust to these potential uses. This may require additional site investigation during the site characterization stage to establish that adequate volumes of the desired site material are available, or can reasonably be removed without tainting with contaminated or undesirable soils. Failure to recognize these conditions during the site characterization phase could result in significant delays at later stage where the details of the final remediation plan are being resolved.

6. DOSE ASSESSMENT

This chapter addresses various aspects of dose assessment as a part of the site characterization process. Dose assessments may not be necessary at sites that will be decommissioned in accordance with the interim cleanup criteria identified in the Site Decommissioning Management Plan Action Plan (57 FR 13389; April 16, 1992). In other cases (e.g., in comparing decommissioning alternatives), a dose assessment may be needed to demonstrate that decommissioning will ultimately allow release of the site for unrestricted use or to compare the relative benefits and costs of the alternatives. The general process for conducting dose assessments includes the following components:

1. Characterization of the exposure setting (e.g., ohysical setting ana potentially exposed populations) at the si*

2. Identification of potential exposure pathways.

3. Quantification of exposure hazard in terms of radionuclide concentrations or exposure rates (e.g., for direct gamma radiation).

4. Estimation of radiological dose using dose assessment codes (e.g., RESRAD (DOE, 1989 and Yu et. al. 1993) and D&D Screen (NRC, 1992b).

6.1 Characterization of Exposure Setting and Potentially Exposed Population

The first step in the preliminary evaluation of potential doses is to assess the information known about the site and its surroundings, its physical characteristics, and extent of site co..tamination. The evaluation results should be used to establish an appropriate source term of radiological contamination corresponding to site-specific conditions and to identify potential exposure pathways and exposure points. Such information may also help in determining site characterization information needs.

6.2 Identification of Potential Exposure Pathways

The exposure pathway is the course through which a radiological or chemical constituent will be transported or conveyed from the source to the exposed individual. The exposure pathway analysis links the source(s), locations, and types of environmental releases with population locations and activity patterns to determine significant pathways of human exposure. An exposure pathway typically comprises four elements:

1. A source term and mechanism for radionuclide and associated chemical releases,

2. A retention or transport medium,

3. A point of potential human contact with the contaminant, and

4. Exposure route into the human (e.g., ingestion, inhalation, or direct radiation) at the contact point.

6.2.1 Sources and Receiving Media

Contaminated materials at decommissioning sites should be identified from review of available information on the site's operational history and waste disposal practices. Contamination may exist in buildings, structures, equipment, tanks, soil, waste disposal trenches, leaking drain lines, plumbing, lagoons, effluent discharge canals, surface water, and groundwater. Release and exposure mechanisms for the contaminated material include surface water runoff, infiltration, groundwater leaching and transport, wind erosion, or direct radiation. The assessment should also identify receiving media for radiological and non-radiological contaminants from past and present operations and may include: surface water, groundwater, soil, sediments, and biota.

6.2.2 Fate and Transport of Contaminants

As part of site characterization, the purpose of the fate and transport analysis is to identify media that are receiving or may receive contaminants and to assess the rate(s) at which the contaminants may be transported or built up through the media. Such analysis should address issues related to type of contaminants occurring in the sources on-site or off-site and the projected future locations and equilibrium (steady state) concentrations. Although the transport of the contaminants may be attenuated by a wide variety of natural processes (e.g., precipitation, bioaccumulation), the analysis should not over-rely on these attenuative processes due to the limited information that will generally be available during site characterization. In addition, overreliance on attenuative processes may defeat the intent of conducting the analysis to identify significant transport pathways as the basis for identifying and prioritizing site characterization needs. Therefore, analyses of transport (e.g., in groundwater or via uptake into plants and animals) should generally give minimal credit for attenuation processes, such as sorption and precipitation. In contrast, the analysis should consider potential increases in contaminant concentrations as a result of such processes as radioactive decay (progeny ingrowth), chemical reconcentration, bioconcentration, and transport enhancement by chelation with organic and other complex compounds. These analyses can be refined at the completion of site characterization on the basis of site-specific information and relevant reference studies.

The physical/chemical and environmental fate properties should be obtained from general literature sources that are properly qualified and relevant. Literature should also be reviewed for updated information on the physical/chemical properties and mobility of the potential contaminants of concern. Specific information regarding physical/chemical properties of contaminants should also be used in the assessment. The assessment should also identify media that are currently contaminated and media that may reasonably become contaminated in the future.

6.2.3 Identification of Exposure Points and Exposure Routes

Exposure points are mainly identified by analyzing if and where any members of the potentially exposed population can contact contaminated media described above. Exposure points are typically located, or assumed to be located, at the location that the contamination can reasonably be contacted (e.g., where people live or work or where a domestic well is located). Prior to release of the site for unrestricted use, the licensee or responsible party may have to restrict access to the site, thus limiting public access to potentially elevated concentrations of radiological contamination. After the site has been released, however, the NRC staff assumes that the site becomes generally accessible for any reasonable use. Therefore, any accessible location on the site may be considered a potential exposure point. Exposure routes should be evaluated in terms of the type of media affected and type of human activities anticipated at the exposure points.

6.3 Quantification of Exposure

Exposure is typically quantified in two major steps. The first step involves estimation of radionuclide concentration; the second pertains to quantification of specific intake or exposure from each pathway.

Contaminant concentration is estimated either by direct determination of radionuclide concentration in the affected media (e.g., soil, groundwater, and surfaces) or by using computational codes that model contaminant transport. When using the direct determination approach, the average concentration should be provided with high confidence interval (typically 90 to 95% or within $\pm 2\sigma$). Lower confidence intervals (e.g., 66%) may be acceptable under certain conditions specifically when there are large number of samples containing radionuclides at low environmental concentration levels and in heterogeneous media. When using the computational approach, sensitivity analysis and uncertainties in the calculational methodology should be provided. In certain cases, due to lack of information, direct measurements and computational models are coupled to obtain more accurate exposure estimates. The degree of model sophistication will depend on the characterization and dose assessment stage and objective. Thus, if site characterization and dose assessment are in the preliminary stage generic models and screening codes can be used. On the other hand if site characterization and dose assessment are conducted at a more advanced stage, specifically for estimating doses to demonstrate compliance with cleanup criteria, a more sophisticated and reliable modeling approach should be considered and, if appropriate, adopted.

Exposures are usually quantified for each specific intake pathway (EPA, 1989c and EPA 1992a,b). For example, exposures are determined from inhalation, ingestion, direct exposure, and drinking groundwater pathways. The derived specific radionuclide concentration for each pathway is then substituted into the dose formula, along with other known parameters such as intake rates, exposure duration, pathway specific period of exposure, and body weight, for calculation of the intake. NRC Policy Guidance and Directive PG-8-08 (NRC, 1994a) provides acceptable exposure parameters and intake rates for assessment of dose and exposure impacts. Appropriate dose conversion factors [e.g., Federal Guidance Report No. 11 (EPA, 1988) and Federal Guidance Report No. 12 (EPA, 1992)] and dose assessment codes should be employed for estimation of dose received from each specific intake (NRC 1992b, DOE, 1989, and Yu et.al 1993). For long-lived radionuclides (e.g., uranium and thorium), dose assessment calculations do not need to be carried out beyond 1000 years.

6.4 Estimation of Radiological Dose Using Dose Assessment Codes

The assessment should estimate radiation doses to potentially exposed individuals and critical population groups. Doses should be expressed in terms of total effective dose equivalents (TEDE 50-year committed dose) due to intakes of radionuclides by inhalation, ingestion, or direct exposure. As stated above, appropriate dose conversion factors (e.g., Federal Guidance Report No. 11) representing effective dose equivalent per unit radionuclide intake should be used in estimating doses. In the unlikely event that individual organ doses approach non-stochastic effect thresholds, the assessment should also present individual organ doses. The assessment should provide an estimate of the total external and internal individual dose (Total Effective Dose Equivalent or TEDE) from all pathways as well as the proportion of the dose attributable to each individual radionuclide and each significant exposure pathway (e.g., ingestion, inhalation, direct exposure). Suitable exposure scenarios for dose assessments are presented in NRC's Policy and Guidance Directive 8-08, *Scenarios for Assessing Potential Doses Associated with Residual Radioactivity* (NRC, 1994a).

Dose assessment codes generally model each significant exposure pathway. For example, contaminant transport models are generally included in such codes for proper assessment of exposure concentration from groundwater used in drinking or irrigation. Other models used in the codes simulate radionuclide leaching from soils and plant uptake. The licensee or responsible party should be careful to ensure that the computer code selected to perform the dose assessment properly represents the transport and exposure pathways, considering site-specific conditions that may affect the validity of particular models or submodels used within the codes. Certain codes may be oversimplified in their methodology and approach and may not account for certain significant pathways in the dose assessment process (e.g., doses from radon inhalation). In other instances, codes may be too sophisticated for the amount of site characterization data available. In addition, code users should ensure that default input parameter values are also reasonably representative of site conditions.

In the preliminary stage of dose assessment, simple computer codes, if properly used, may be adequate to prepare dose estimates. Such computer codes include: RESRAD [DOE/CH/8901 (DOE, 1989); Gilbert et. al. 1989; and Yu et. al. 1993], NRC D&D Screen (methodology as described in NRC, 1992b), GENII (Napier et. al 1988), and MEPAS (Droppo et. al., 1989). These codes should be applied with caution since some of the default parameters and assumptions may be unjustified and/or inapplicable to site specific conditions. Therefore, assessors should consult NRC staff on selection of dose assessment codes to ensure that the models are representative or conservatively bound potential doses, especially when default parameters are selected. The assessment should justify the selection of default or alternative site parameters and the computer code itself (DOE, 1992, and ANL, 1993). In some cases, it may be more appropriate to rely upon hand calculations for certain pathways (e.g., direct exposure) in conjunction with computer model estimates for others. Licensees and responsible parties are encouraged to contact the NRC staff in advance of the modeling to discuss plans for the assessment and the appropriate use of assumptions and assessment techniques.

In the advanced assessment stage, however, specifically when dose assessment is conducted for complex sites, more site-specific data and possibly more elaborate and specific codes will be necessary. If necessary, screening codes can be supplemented by either coupling them with more comprehensive contaminant transport models (e.g., 1-D, 2-D, or 3-D transport models) or by using more elaborate independent codes. For example, a more sophisticated groundwater transport model may be necessary to design and plan a groundwater corrective action program involving withdrawal and injection wells. At this stage, more site-specific parameters should become available through the site characterization process (Figure 2). After they are appropriately assessed, these parameters should be used as input for the more sophisticated code. Selection of the applicable code and model complexity will depend on the purpose and objectives of the dose assessment and on the type, amount, and quality of the physical and the environmental data available. Assessments that use computer models should generally include a sensitivity analysis that compares the effect of changes of input parameters on the resulting estimates of dose, concentration, or other dependent variable. The assessment should also describe the uncertainties and limitations associated with the assessment results and consider these factors in applying the results of the assessment.

7 REFERENCES

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APPENDIX I

FORMAT OF SITE CHARACTERIZATION REPORT

APPENDIX I

FORMAT OF SITE CHARACTERIZATION REPORT

EXECUTIVE SUMMARY

1. INTRODUCTION

1.1 Background
1.2 Purpose, Scope, And Objectives of Characterization Activities
1.3 Decommissioning Criteria and Guidelines
1.4 Report Organization

2. GENERAL DESCRIPTION OF THE SITE

2.1 Site Location and Description
2.2 Site History
2.3 General Physical Setting
2.4 Exposed Population
2.5 Preliminary Evaluation of Contamination

3. EXTENT AND CONCENTRATION OF CONTAMINATION

3.1 Background Characterization
3.1 Characterization of Source of Contamination
3.2 Radiological, Chemical, and Physical Characterization of Contaminants
3.3 Design of Survey and Sampling of Contamination
3.4 Extent of Contamination
- 3.4.1 Surface Water and Sediments
- 3.4.2 Soils and Vadose Zone
- 3.4.3 Groundwater
- 3.4.4 Structures and Equipment
- 3.4.5 Air

4. PHYSICAL CHARACTERISTICS OF THE SITE

4.1 Surface Features
4.2 Meteorology and Climatology
4.3 Surface Water Hydrology
4.4 Geology
4.5 Hydrology
- 4.5.1 Identification and Characterization of Hydrogeologic Units (Soil, Vadose, and Saturated Zones)
- 4.5.2 Groundwater Flow and Transport Models
- 4.5.3 Hydrogeologic Characterization Methods and Monitoring Methods

5. CHARACTERIZATION ASSOCIATED WITH RISK/DOSE ANALYSIS

5.1 Characterization of Exposure Setting and Potentially Exposed Population
5.2 Identification of Potential Exposure Pathways
- 5.2.1 Sources and Receiving Media
- 5.2.2 Fate and Transport of Contaminants
- 5.2.3 Identification of Exposure Points and Routes

5.3 Quantification of Exposure
5.4 Estimation of Radiological Doses Using Models and Codes

6. SUMMARY AND CONCLUSION

APPENDIX II

RADIOLOGICAL SURVEY FORMS

FIELD RADIATION SURVEY FORM

1.) Instrument Type/Model ______________________ Probe Model ______

2.) Operational Check: Before ______ After ______ 3.) Cal. Date ___________

4.) Radiation Type: _____Alpha _____Beta _____Gamma

5.) Date of Survey __________ 6.) Title of Survey ________________

7.) Location ____

____

8.) Data BAG Location__________ ______ Value:____________

BAG Location________________ Value:____________

Location Number	Location (Map on Back)	Exposure Units ( )

9.) Remarks:____

____

10.) Surveyor's Name ____________________ Signature ____________________

FIELD RADIATION EXPOSURE DATA FORM

(PRESSURIZED ION CHAMBER)

1. Instrument Model: _____ RSS-111 _____ RSS-112 2. Instrument No. ________

3. Location ____

________________________________ Long. __________ Lat. __________

4. START:

Date ________________ Integrator ________________________

Time ________________ Exposure Rate ______________________

5. Recorder Chart Time ______________________ inches/hour

6. STOP:

Date ________________ Integrator ________________________

Time ________________ Exposure Rate ______________________

7. Background: Location ________________________ Value ________________ μR/hr

8. Remarks ____

____

9. Operator's Name ______________________ 10. Signature ______________________

INDOOR RADON MEASUREMENT DATA FORM

1. Sample No. ____________ 2. Canister No. ____________

3. Location/Address ______________________________

______________________________ Long. ________ Lat. ________

4. Multi-Level Dwelling ____________ 5. Basement (full/half) ________

6. Location of Measurement (Room) ______________________________

7. Start: ________ ________ ________ Time: ________ ____ AM ____ PM

Month Day Year

8. Stop: ________ ________ ________ Time: ________ ____ AM ____ PM

Month Day Year

9. Condition of Canister ______________________________

____

10. Comments ______________________________

____

11. Sampler's Signature ____________ 12. Name ____________ (Print)

AMBIENT RADON MEASUREMENT DATA FORM

1. Electret Serial No. ______________ 2. TLD Serial No. ________________
____
____

3. Electret Type ____

4. Measurement Location ____
________________________________ Long. __________ Lat. __________

5. Start Exposure Date: ________ Time: ________ Initial Voltage: __________

6. EIC Condition ____
____

7. Stop Exposure Date: ________ Time: ________ Final Voltage: __________

8. Change in EIC Condition ____
____

9. Comments ____
____

10. Sampler's Signature ____________________ 11. Name ____________________ (Print)

12. Cal Factor ____________________ 13. BKG Factor ____________________

APPENDIX III

SAMPLING, CHAIN OF CUSTODY AND QA/QC FORMS

Sample container label.

Sample No. ______________________________

Sample Location __________ ______________

Date/Time ________________________________

Project No.______________Sample Size ________

Preservatives _____________Sample Type _______

Analysis _________________________________

Sampled By _______________________________

Receipt for samples form.

RECEIPT FOR SAMPLES

WORK NO.

PROJECT NAME

NAME OF FACILITY

SAMPLER(S): (Signature)

FACILITY LOCATION

SPLIT SAMPLES OFFERED

☐ Accepted ☐ Declined

STA. NO.	DATE	TIME	COMP.	GRAB	SPLIT SAMPLES	SAMPLE NUMBERS	STATION DESCRIPTION	NO. OF CONTAINERS	REMARKS

TRANSFERRED BY: (Signature)

DATE TIME

RECEIVED BY: (Signature) TELEPHONE

TITLE DATE TIME

DISTRIBUTION: Original to POL; 2nd Copy to Private Party

Chain-of-custody record form.

CHAIN OF CUSTODY RECORD

WORK ASSIGNMENT #	PROJECT NAME	# of CONTAINERS	ANALYSIS REQUESTED	FOR LABORATORY USE

Client Name

Project Manager

Requested Comp. Date

Notify ________ upon receipt? ☐ Yes ☐ No

Laboratory Prefix

Study I.D.

Pg ________ of ________

Item No.	Date	Time	Matrix	Sample I.D.	# of CONTAINERS									Laboratory I.D.	Comments

Sampled by and Title	Date/Time	Relinquished by:	Date/Time	QC Level 1 2 3	
Received by:	Date/Time	Relinquished by:	Date/Time	COC	ICE
Received by:	Date/Time	Relinquished by:	Date/Time	ANA REQ	TEMP
Remarks		Sample shipped via UPS FED-EX HAND OTHER	Air Bill #	Cust. Seal	pH
				Sample Cond.	

CUSTODY SEAL

Date

Signature

SOIL SAMPLING DATA FORM

1. Date/Time ______________________ 2. Sample No. ____________________

3. Title of Study ____

4. Location ____

____________________________________ Long. ________ Lat. ________

5. Location Number ____________ 6. Sample Size/Container ______________

7. Weather: Wind ______ Precipitation ______ Air Temperature ______

8. Sampling Method (description) ______________________________________

____

____

9. Visual characterization ____

____

____

10. Analyze for: ____

____

11. Remarks ____

____

____

12. Sampler's Signature _________________________ 13. Date/Time ________

SEDIMENT SAMPLING DATA FORM

1. Date/Time ____________________ 2. Sample No. ______________________

3. Title of Study ____

4. Location ____

______________________________________ Long. _________ Lat. _________

5. Location Number _____________ 6. Sample Size/Container ______________

7. Sampling Method (description) ____ ___________________________________

____

____

8. Visual characterization ____

____

____

9. Analyze for: ____

____

10. Remarks ____

____

____

11. Sampler's Signature _____________________ 12. Date/Time _____________

SURFACE WATER SAMPLING DATA FORM

1. Date/Time ______________ 2. Water or Filtrate Sample No. ______________

3. Solids Sample No. ______________

4. Title of Study ____

5. Location ____

______________________________ Long. ________ Lat. ________

6. Location Number ______________ 7. Sample Size/Container ______________

8. Weather: Wind ________ Precipitation ________ Air Temperature ________

9. Sample pH _____ Temp. _____ 10. Depth(s) ______________________

11. Sampling Method (description) ______________________________

____

____

12. Filtered Sample? _____ 13. Filter type/size/No. Used ______________

14. Preservation ____

15. Analyze for: Water - ______________________________________

Solids - ____

16. Remarks ____

____

17. Sampler's Signature ______________________ 18. Date/Time ______________

River Flow-Rate Data Form

Study ____________________ Date ____

Method: Two Point Method ________ Sixth-Tenths Method ________ River Width ____

Location on River ____________________

Data

Location No.	Depth (ft)	Two-Point Method: 20% Depth Velocity (ft/min) #1	#2	#3	Avg	80% Depth Velocity (ft/min) #1	#2	#3	Avg	6/10 Depth Method: Velocity (ft/min) #1	#2	#3	Avg
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

Comments ____________________

____

Name ____________________

DRINKING WATER SAMPLING DATA FORM

1. Date/Time ____________________ 2. Sample No. ____________________

3. Title of Study ____

4. Location (Include Address) ______________________________________

________________________________ Long. ________ Lat. ________

5. Location Number ____________ 6. Sample Size/Container ____________

7. Serviced: Population ______________ Households ______________

8. On-line Filtering/Purification ________________________________

9. Sample pH _____ Temp. _____ 10. Well/Tap ______________________

11. Sampling Method (description) ________________________________

____

12. Purge: Time ______________ Est. Volume ______________________

13. Preservation ____

14. Analyze for: ____

15. Remarks ____

____

16. Sampler's Signature ____________________ 17. Date/Time __________

GROUNDWATER SAMPLING DATA FORM

1. Date/Time ________________ 2. Water or Filtrate Sample No. ____________

3. Solids Sample No. ________________

4. Title of Study ____

5. Location ____

____ Long. ________ Lat. ________

6. Well Number __ ___ ____ ____ 7. Sample Size/Container ________________

8. Depth-to-Water Level ____ft. Water Depth ____ft. Water Temp.____F° pH____

9. Water Volume in Well ____________ gal. 10. Volume Purged ____________ gal.

11. Type Sampler/Method ____

____

12. Filtered Sample (Y,N) _____ Filter Type/Size/No. Used ________________

13. Preservation ____

14. Analyze for: ____

____

15. Remarks ____

____

____

16. Sampler's Signature ________________________ 17. Date/Time ______________

HIGH-VOLUME AIR SAMPLING DATA FORM

1. Date/Time ______________________ 2. Sample No. ____________________

3. Title of Study ____

4. Location ____

____________________________________ Long. ________ Lat. ________

5. Location No. _____________________ 6. Sample Type _________________

7. Date	Time	Magnehelic Reading	Volume (m^3/hr)
ON __________	____	______________	__________
__________	____	______________	__________
__________	____	______________	__________
__________	____	______________	__________
OFF __________	____	______________	__________

8. Total Sample Volume ____________

9. Analyze for: ____

____

10. Remarks ____

____

____

11. Sampler's Signature ____________________ 12. Date/Time ___________

LOW-VOLUME AIR SAMPLING DATA FORM

(RADeCO Model HD-28B)

Date/Time: ____________________ **Sample No.:** ________________________

Study Title: ____

Location: ____

______________________________ **Long.** ______________ **Lat.** _______________

Location No.: ________________ **Sample Type:** ______________________

Sampler S/N: ________________ **Filter Type/Size:** ____________________

	Date	Time	Elapsed Timer	Pump Head (in. of Hg)	Δ° Paper (in. of Hg)	Rotameter (cfm)
ON						
OFF						

Analyze for: ____

____

Remarks: ____

____

____

Sampler's Name: ____________________ **Signature:** ______________________

WELL SUMMARY INFORMATION

Hole No. ______
Observer ______
Start Date ______
Completion Date ______

Project ______ Location ______

Drilling Data

Drilling Rig Type ______ Sample Type ______
Method of Drilling ______ Sample Interval ______
Bit or Auger Size ______ I.D. of Sampler ______

Zone of Loss/Increased Circulation:
from ______ to ______ Source of Drilling Water ______
from ______ to ______ Drilling Additives ______
from ______ to ______ First Water Encounter (depth) ______

Hole Data

Hole Diameter ______ Drilled from ______ to ______
Hole Depth ______ Cored from ______ to ______
Surface Casing: Yes ______ No ______
Type ______ I.D. ______ Depth from ______ to ______

Aquifer Data

Aquifer Material ______ Aquifer Thickness ______
Elev. Top of Aquifer ______ Elev. Bottom of Aquifer ______
Confined/Unconfined Consolidated/Unconsolidated

Well Data

Multilevel Piezometer: Yes ______ No ______
Casing: Type ______ I.D. ______ Length ______ Top Elev. ______
Screening: Type ______ Slot Size ______ Interval: from ______ to ______
from ______ to ______

Filter Material ______ Interval: from ______ to ______
Seal: Type ______ Interval: from ______ to ______
from ______ to ______

Backfill: Type ______ Protective Casing and Lock: Yes ______ No ______
Water Level ______ Method of Measurement ______
Geophysical Logs ______ Date ______ Time ______
Logger T.D. ______ Type of Well Development ______

Well Construction

Comments: ______

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SAMPLE TICKET DOCUMENTATION

Sampler ______________________ Date ______________ Time ______________

All Samples:

Type: Stream ____ Lake ____ Well ____ Spring ____ Other ______________________

Location: Narrative Description ______________________________ State ____________

______________________________ County ____________

Legal Description: Meridian ________ Township ________ Range ________ Section ________

Latitude ____ Deg. ____ Min. ____ Sec. ____ Longitude ____ Deg. ____ Min. ____ Sec. ____

Sample Appearance (odor, color, TSS) ____

____

Temperature ________°C

Surface Samples: Gauge Height (ft) ________ (If not available, empirically describe streamflow, etc.)

____

____

____

Well Samples: Type of Well ______________________ Depth to Water (ft) ________

Date Drilled ______________________ Depth ______________________

Water-Bearing Formation ____

Bore Volumes Removed Before Sampling ____

Remarks (discuss filtration problems, recovery time for well, etc.): ______________________

____

____

____

CHAIN OF CUSTODY RECORD

				SAMPLERS (Signature)					
STATION NUMBER	STATION LOCATION	DATE	TIME	SAMPLE TYPE			SEQ. NO.	NO. OF CONTAINERS	ANALYSIS REQUIRED
				Water		Air			
				Comp.	Grab.				

Relinquished by: (Signature)		Received by: (Signature)	Date/Time
Relinquished by: (Signature)		Relinquished by: (Signature)	Date/Time
Relinquished by: (Signature)		Received by: (Signature)	Date/Time
Received by: (Signature)		Received by Mobile Laboratory for field analysis: (Signature)	Date/Time
Dispatched by: (Signature)	Date/Time	Received for Laboratory by:	Date/Time
Method of Shipment:			

Distribution: Orig.—Accompany Shipment
1 Copy—Survey Coordinator Field Files

QUALITY ASSURANCE DOCUMENTATION FOR FIELD CHEMICAL ANALYSES

Part I. Documentation Required Before Going to the Field

1. Carbonate and Bicarbonate

a) pH/Buret:

Source of Titrant____________ Calibration Value__________

b) Test Kit:

Titration Cartridge Normality____________________________

Checked Normality in Laboratory Yes___ No___

2. Specific Conductance

Source of Conductance Standard______ Preparation Date______

Measured Cell Constant_____ Manufacturer's Cell Constant____

3. Nitrate

Source of Stock Nitrate Standard____ Preparation Date______

Working Standard Preparation Date_______________

4. Uranium

Source of Stock Uranium Standard_______ Preparation Date____

Part II. Documentation of Actual Conditions of the Sample

Complete Prior to Working on Each Sample:

Sample Conditions: Clear________Colored________Sediment_______.

(Some narrative description may be necessary.)

Part III. Documentation Required for Field Measurements

1. Temperature: ________°C

2. pH

   Time________________

   Measurement Conditions: In Situ______ Open Container______ Air Exclusion________

   Time of Last Two-Buffer Calibration ________________

   Buffer Temperature at Calibration ________________

   Sample Temperature ________________

   Sample Specific Conductance ________________

   Sample pH ________________

3. Carbonate and Bicarbonate

   a) pH/Buret:

   Time________________

   Temperature of Titrant________________

   Sample pH________________

ΔpH/Δml Carbonate End Point:		ΔpH/Δml Bicarbonate End Point:	
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______
Buret Reading______	pH______	Buret Reading______	pH______

b) Test Kit:

Time ____________

Normality of Titration Cartridge ____________

Phenolphthalein Alkalinity ____________

Total Alkalinity ____________

4. Specific Conductance

Time ____________

Measurement Conditions: In Situ ______ Open Container ______ Air Exclusion ______

Time of Last Calibration Check ____________

Buffer Temperature at Calibration ____________

Sample Temperature ____________

Specific Conductance at 25°C ____________

5. Dissolved Oxygen (DO)

Time ____________

Date and Time of Last Zero Check with Sulfite Solution ____________

Atmospheric Pressure ____________ + Elevation of measurement

Temperature of Calibration Chamber ____________

DO Saturation from Table 5-1 ____________

DO Saturation Corrected for Pressure ____________

Calibration Value ____________

Sample Temperature ____________

Sample Dissolved Oxygen ____________

6. Nitrate

Time________________

Kit Results________________________

7. Eh

Time________________

Measurement Conditions: In Situ______ Open Container______ Air Exclusion______

Dissolved Oxygen Result ________________

Temperature of ZoBell Solution ________ ________ (should be same as sample)

Eh of ZoBell ________________

Theoretical Eh of ZoBell ________________

Sample Temperature ________________

ZoBell Eh at Sample Temperature ________________

Theoretical Eh of ZoBell at Sample Temperature ________________

Eh of Sample ________________

8. Uranium

Time________________

Time of Last Calibration Check ________________

Sample Dilution Factor ________________

Instrument Reading_____ +2 ppb Spike_____ +4 ppb Spike_____

Sample No.____________________

Project No.____________________

Project Name____________________

Name________________ Date__________ Time In_____ Time Out_____

SITE LOCATION:

Same as__________________

Meridian___Twp___ NS Range___ EW Sec___ 1/64___ 1/16___ 1/4___

Latitude: Deg___ Min___ Sec___ Longitude: Deg___ Min___ Sec___

Locality: Name__________________ County_______ State________

SAMPLE LOCATION:

Same as__________________

Grid__________ NS Grid__________ EW Grid Origin____________

Elevation____________ Sample Depth______ Geologic Unit________

Soil Series__________________Soil Texture__________________

SAMPLE TYPE: (check)

ROCK_______ Grab_______ Core_______ Cutting_______

SOIL____ Surface____ Profile____ Composite___ Core___ Cutting___

Sampling Method__________________________

Comments: