5 FINAL STATUS SURVEY PLAN

5.1 Introduction

The Final Status Survey (FSS) Plan describes the methods to be used in planning, designing, conducting, and evaluating final status surveys at the YNPS site. These surveys serve as key elements to demonstrate that the dose from residual radioactivity is less than the maximum annual dose criterion for license termination for unrestricted use specified in 10CFR20.1402 (Reference 5-1). The additional requirement of 10CFR20.1402, that residual radioactivity at the site be reduced to levels that are as low as reasonably achievable (ALARA), is addressed in Section 4. The Final Status Survey Plan was developed using the guidance of NUREG-1575, "The Multi-Agency Radiological Site Survey and Investigation Manual (MARSSIM)" (Reference 5-2); Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Nuclear Power Reactors" (Reference 5-3); NUREG-1727, "NMSS Decommissioning Standard Review Plan," (Reference 5-4); and NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance," (Reference 5-5).

The FSS process described in the survey plan adheres to the guidance of MARSSIM. However, advanced survey technologies may be used to conduct radiological surveys that can effectively scan 100% of the surface and record the results. This survey plan allows for the use of these advanced technologies, where survey quality and efficiency can be increased, as long as the survey results are at least equivalent, in terms of their statistical significance, to those that would have been obtained using the non-parametric sampling methods of MARSSIM. In cases where advanced survey technologies are to be used, a technical evaluation will be developed to describe the technology to be used and to demonstrate how the technology meets the objectives of the survey. These technical evaluations will be referenced, as appropriate, in Final Status Survey Reports.

5.2 Scope

The FSS Plan encompasses the radiological assessment of impacted structures, systems and land areas for meeting the dose rate criterion for unrestricted release specified in 10CFR20.1402. In addition, Section 5.6.3.2.4 addresses the plan for the assessment of groundwater.

5.3 Summary of FSS Process

The FSS provides data to demonstrate that radiological parameters satisfy the established guideline values and conditions. The primary objectives of the final status survey are to:

- verify survey unit classification,

- demonstrate that the potential dose from residual radioactivity for each survey unit is below the release criterion for each survey unit, and

- demonstrate that the potential dose from small areas of elevated activity are below the release criterion.

The final status survey process consists of four principal elements:

- planning,
- design,
- implementation, and
- assessment.

Survey planning includes review of the Historical Site Assessment (HSA) and other pertinent characterization information to establish the radionuclides of concern and the survey unit classifications. Survey units are fundamental elements for which final status surveys are designed and executed. The classification of a survey unit determines how large it can be in terms of surface area. If any of the radionuclides of concern are present in background, the planning effort may include establishing appropriate reference areas to be used to establish baseline concentrations for these radionuclides and their variability. A reference coordinate system is used for documenting locations where measurements were made and to allow replication of survey efforts if necessary.

Before the survey process can proceed to the design phase, concentration levels that represent the maximum annual dose criterion of 10CFR20.1402 must be established. These concentrations are established for either surface contamination or volumetric contamination. They are used in the survey design process to establish the minimum sensitivities required for the available survey instruments and techniques, and in some cases, the spacing of fixed measurements or samples to be made within a survey unit. Surface or volumetric concentrations that correspond to the maximum annual dose criterion are referred to as Derived Concentration Guideline Levels, or DCGLs. A DCGL established for the average residual radioactivity in a survey unit is called a $DCGL_W$. Values of the $DCGL_W$ may then be increased through the use of area factors to obtain a DCGL that represents the same dose to an individual for residual radioactivity over a smaller area within a survey unit. The scaled value is called the $DCGL_{EMC}$, where EMC stands for elevated measurement comparison.

After the $DCGL_W$ is established, a survey design is developed that selects the appropriate survey instruments and techniques to provide adequate coverage of the unit through a combination of scans, fixed measurements, and sampling. This process ensures that data of sufficient quantity and quality are obtained to make decisions regarding the suitability of the survey design assumptions and whether the unit meets the release criterion. Approved site procedures will direct this process to ensure consistent implementation and adherence to applicable requirements.

Survey implementation is the process of carrying out the survey plan for a given survey unit. This may consist of a combination of scan measurements, fixed measurements, and/or collection and analysis of samples.

The Data Quality Assessment (DQA) approach is applied to FSS results to ensure their validity and to demonstrate that the objectives of the FSS are met. Data assessment includes data verification and validation (V&V), review of survey design bases, and data analysis. For a given survey unit, the survey data are evaluated to determine if the residual activity levels in the unit meet the applicable release criterion and if any areas of elevated activity exist. In some cases, data evaluation will simply serve to show that all of the measurements made in a given survey unit were below the applicable $DCGL_W$. In that case, demonstrating compliance with the release criterion is a simple matter and requires little in the way of analysis. In other cases, residual radioactivity may exist where there are measurement results both above and below the $DCGL_W$. In these cases, statistical tests must be performed to make a decision as to whether the unit meets the release criterion. The statistical tests that might be required to make decisions regarding the residual activity levels in a survey unit relative to the applicable $DCGL_W$ must be considered in the survey design to ensure that a sufficient number of measurements are collected.

MARSSIM specifies two non-parametric statistical tests to be applied to final status survey data to evaluate whether a set of measurements demonstrates compliance with the release criterion for a given survey unit. These statistical tests are discussed in detail in Section 5.7.

Quality assurance and control measures, satisfying the criteria of Appendix B to 10CFR50 as applicable, are employed throughout the final status survey process to ensure that decisions are made on the basis of data of acceptable quality. Quality assurance and control measures are applied to ensure:

- the plan is correctly implemented as prescribed,
- Data Quality Objectives are properly defined and derived,
- data and samples are collected by individuals with the proper training following approved procedures,
- instruments are properly calibrated,
- collected data are validated, recorded, and stored in accordance with approved procedures,
- required documents are properly maintained, and,
- if necessary, corrective actions are prescribed, implemented and followed up.

These measures apply to any services provided in support of final status survey.

Survey results will be converted to appropriate units (i.e., either dpm/100 cm^2 or pCi/g) and compared to investigation levels to determine appropriate follow-up action. Measurements exceeding investigation levels will be verified and investigated and, following confirmatory measurement(s), the affected area may be remediated and/or re-classified and a re-survey performed consistent with the guidance in MARSSIM (Section 8.5.3, "If the Survey Unit Fails") and commensurate with the classification and extent of contamination.

It is anticipated that final status survey results will be documented and made available to the NRC for survey areas rather than for individual survey units. Reports will be compiled after final status survey activities for all of the survey units for a given area are completed. The information to be contained in the final status survey report is specified in Section 5.8 of the LTP. This approach should minimize the submittal of redundant historical assessment information and provide for a logical approach to perform reviews and independent verification.

5.4 Final Status Survey Planning

5.4.1 Data Quality Objectives

The Data Quality Objective (DQO) process is incorporated as an integral component of the data life cycle at YNPS. The DQO process is used in the planning phase for scoping, characterization, remediation, and final status survey plan development using a graded approach. Survey plans that are complex or that have a higher level of risk associated with an incorrect decision (such as final status surveys) would require significantly more effort than a survey plan used to obtain data relative to the extent and variability of a contaminant. This process, described in MARSSIM, is a series of planning steps found to be effective in establishing criteria for data quality and developing survey plans. Data Quality Objectives allow for systematic planning and are specifically designed to address problems that require a decision to be made and provide alternate actions. Furthermore, the DQO process is flexible in that the level of effort associated with planning a survey is based on the complexity of the survey and nature of the hazards. Finally, the DQO process is iterative allowing the survey planning team to incorporate new knowledge and modify the output of previous steps to act as input to subsequent step. A Final Status Survey Quality Assurance Project Plan will be developed that provides a detailed description of the application of the DQO process to the different elements of the final status survey.

The DQO process consists of performing the following seven steps:

- State the Problem
- Identify the Decision
- Identify the Inputs to the Decision
- Define the Boundaries of the Decision
- Develop a Decision Rule
- Specify Tolerable Limits on Decision Errors
- Optimize the Design for Obtaining Data

The actions taken to address these DQO process steps during the planning of a final status survey for a particular survey area are addressed below.

- **State the Problem**

  The first step of the planning process consists of defining the problem. This step provides a clear description of the problem, identification of planning team members (especially the decision-makers), a conceptual model of the hazard to be investigated and the estimated resources. The problem associated with an FSS is to determine whether an area meets the radiological release criterion of 10CFR20.1402.

- **Identify the Decision**

  This step of the DQO process consists of developing a decision statement based on a principal study question (i.e., the stated problem) and determining alternative actions that may be taken based on the answer to the principal study question. Alternative actions identify the potential measures to resolve the problem. The decision statement combines the principal study question and the alternative actions into an expression of choice among multiple actions. For FSS the principal study question could be, "Does residual radioactive contamination present in the survey unit exceed the release criteria?" The alternative actions may include no action, investigation, re-survey, remediation and re-classification.

- **Identify Inputs to the Decision**

  The information required depends on the type of media under consideration and whether existing data are sufficient or new data are needed to make the decision. If the decision can be based on existing data, then the data source(s) will be documented and evaluated to ensure reasonable confidence that the data are acceptable. If new data are needed, then the type of measurement (e.g., scan, direct measurement and sampling) will need to be determined.

  Sampling methods, sample quantity, sample matrix, type(s) of analyses and analytic and measurement process performance criteria, including detection limits, are established to ensure adequate sensitivity relative to the action level and to minimize bias. Action levels provide the criteria for choosing among alternative actions (e.g., whether to take no action, perform confirmatory sampling). These action levels may be radioactivity concentration (pCi/g) or measurement device response (count rate corrected for background). Typical investigation levels for FSS are derived from Table 5-2, depending upon the final classification of the survey unit. FSS will include survey unit specific action levels and their bases.

- **Define the Boundaries of the Study**

  This step of the DQO process includes identification of the target population of interest, the spatial and temporal features of the population pertinent to the decision, time frame for collecting the data, practical constraints and the scale of decision making. For the FSS, the target population is the set of samples or direct measurements that constitute an area of interest (i.e., the survey unit). The medium of interest (e.g., soil, water, concrete) is specified during the planning process. The spatial boundaries include the entire area of interest including soil depth, area dimensions, contained water bodies and natural boundaries, as needed. Temporal boundaries include those activities impacted by time-related events including weather conditions, seasons (i.e., more daylight available in the summer), operation of equipment under different environmental conditions, resource loading and work schedule.

- **Develop a Decision Rule**

  This step of the DQO process develops the binary statement that defines a logical process for choosing among alternative actions. The decision rule is a clear statement using the "If...then..." format and includes action level conditions and the statistical parameter of interest (e.g., mean of data). Decision statements can become complex depending on the objectives of the survey and the radiological character of the affected area.

- **Specify Tolerable Limits on Decision Errors**

  This step of the DQO process incorporates hypothesis testing and probabilistic sampling distributions to control decision errors during data analysis. Hypothesis testing is a process based on the scientific method that compares a baseline condition to an alternate condition. The baseline condition is technically known as the null hypothesis. Hypothesis testing rests on the premise that the null hypothesis is true and that sufficient evidence must be provided for rejection.

  The primary consideration during FSS will be demonstrating compliance with the release criteria. The following statement may be used as the null hypothesis at YNPS: "The survey unit exceeds the release criteria."

  Decision errors occur when the data set leads the decision-maker to make false rejections or false acceptances during hypothesis testing. The α error (Type I error) is set at 0.05 (5%), and a nominal value of 0.05 (5%) has been established for the β error (Type II error). Another output of this step is assigning probability limits to points above and below the gray region where the consequences of decision errors is considered acceptable. The upper bound corresponds to the release criteria. The Lower Bound of the Gray Region (LBGR) is determined in this step of the DQO process. LBGR is influenced by a parameter known as the relative shift. The relative shift is set between (and including) 1 and 3. If the relative shift is not between (or including) 1 and 3, then the LBGR is adjusted.

  Graphing the probability that a survey unit does not meet the release criteria may be used during FSS. This graph, known as a power curve, may be performed retrospectively (i.e., after FSS) using actual measurement data. This retrospective power curve may be important when the null hypothesis is not rejected (i.e., the survey unit does not meet the release criteria) to demonstrate that the DQOs have been met.

- **Optimize the Design for Obtaining Data**

  The first six steps are the DQOs that develop the performance goals of the survey. This final step in the DQO process leads to the development of an adequate survey design.

5.4.2 Classification of Survey Areas and Units

The adequacy of the final status survey process rests upon partitioning the site into properly classified survey units of appropriate physical area. Section 2 of the LTP discusses in detail the HSA for the YNPS site and the classifications assigned to all of the site structures and grounds. Characterization is an ongoing effort throughout the decommissioning process, and survey unit classifications may be modified on the basis of new characterization information or impacts from decommissioning activities. The process described in LTP Section 1.6 will be used to evaluate the modifications to unit classifications to determine whether prior notification by the NRC is required. Survey areas have been determined as described in Section 2.1.1 of this LTP.

A survey area may consist of one or more survey units. A survey unit is a physical area consisting of structures or land areas of a specified size and shape which will be subject to a final status survey. Compliance with the applicable criteria will be demonstrated for each survey unit.

Survey units are limited in size based on classification, exposure pathway modeling assumptions, and site-specific conditions. The surface area limits, used in establishing the initial set of survey units for the YNPS Final Status Survey Plan, are provided in Table 5-1 for structures and land areas. The area limits for structures refer to floor area, and not the total surface area, which would include the walls and ceiling. This is consistent with the guidance in Table A.1 of Appendix A to NUREG-1757) and MARSSIM. The floor area limits given in Table 5-1 were also used to establish survey unit sizes for structures such as roofs or exterior walls of buildings. The limits given in Table 5-1 will also be used should the need arise to establish any new survey units beyond the initial set given in this plan.

As indicated in LTP Section 2, areas of YNPS that are classified as impacted have been divided into survey units to facilitate survey design. Each survey unit has been assigned an initial classification based on the site characterization process and the historical site assessment.

Table 5-1
YNPS Survey Unit Surface Area Limits

Survey Unit Classification	Surface Area Limit
Class 1: Structures (floor area) Land areas	 ≤ 100 m^2 ≤ 2,000 m^2
Class 2: Structures (floor area) Land areas	 100 m^2 ≤ area ≤ 1,000 m^2 2,000 m^2 ≤ area ≤ 10,000 m^2
Class 3: Structures (floor area) Land areas	 no limit no limit

A survey unit can have only one classification. Thus, situations may arise where it is necessary to create new survey units by subdividing areas within an existing unit. For example, residual radioactivity may be found within a Class 3 survey unit, or residual radioactivity in excess of the $DCGL_W$ may be found in a Class 2 unit. In such cases, it may be appropriate to define a new survey unit within the original unit that has a lower (more restrictive) classification. Alternately, the classification of the entire unit can be made more restrictive.

5.4.3 Reference Coordinate Systems

Measurements and sample locations can be identified in one of two ways: using a benchmark location or a global positioning system (GPS). If benchmark is used, that benchmark (origin) will be provided on the map or plot included in the final status survey package. Any coordinate systems used for surveys will typically take the form of a grid of intersecting, perpendicular lines; but other patterns (e.g., triangular and polar) may be used as convenient. Physical gridding of a survey unit will only be done in cases where it is beneficial and cost effective to do so. When physical gridding is used, benchmark locations will be designated by either marking a spot with surveyor's paint (or equivalent) for indoor areas or setting an iron pin (or equivalent) for outdoor areas. If needed, grid lines or measurement locations will be marked (e.g., with chalk lines, paint, surveyor's flags), as appropriate. Global positioning systems may also be used as practical.

5.4.4 Reference Areas and Materials

The DQO process will be used during the planning phase in the preparation of a final status survey plan to determine whether media specific backgrounds, ambient area background or no background will be applied to a survey area or unit. The approach used for a specific survey unit will be based on the survey unit classification and the DCGLs.

If applied, media specific backgrounds will be determined via measurements made in one or more reference areas and on various materials selected to represent the baseline radiological conditions for the site. The determination of media specific background will be controlled with a documented survey plan, which will include the DQO process. These data will be evaluated in a technical support document and available for inspection by the NRC. This process will ensure that the collected data will meet the needs of the final status survey. The collected data may be used as the reference area data set when using the Wilcoxon Rank Sum test, or, for survey units with multiple materials, background data may be subtracted from survey unit measurements (using paired observations) if the Sign Test is applied.

Depending on the values of the DCGLs, an alternative method to using material specific backgrounds may be used during final status surveys. This alternative method will involve the determination of the ambient area background in the survey unit and will only be applicable to beta-gamma detecting instruments. This determination will be made prior to performing a final status survey at a location within a survey area that is of sufficient distance (or attenuation) from the surfaces to eliminate beta particles originating from the surfaces from reaching the detector. At such a location, the ambient background radiation will be due only to ambient gamma radiation and will be a background component of surface measurements. The average background determined at this location can be used as a conservative estimate since it is expected to be less than the material specific background for the material in the room because it does not fully account for the naturally occurring radioactivity in the materials. Using this lower ambient background will result in conservative calculated residual radioactivity levels. If the average background reading exceeds a predetermined value, the survey would be terminated and an investigation performed to determine and eliminate the reason for the elevated reading. Each of the survey unit readings would subtract this average background value and the Sign Test applied.

Whether or not they are radionuclide-specific, background measurements should account for both spatial variability over the area being assessed and the precision of the instrument or method being used to make the measurements. Thus, the same materials or areas may require more than one background assessment to provide the requisite background information for the various survey instruments or methods expected to be used for final status surveys. The result of these background assessments will provide the basis for determining the mean and its associated standard deviation.

The presence of the spent fuel stored at the Independent Spent Fuel Storage Installation (ISFSI) will increase gamma radiation levels at close distances to the storage pad. The specific region where this elevated gamma radiation will influence the final status surveys has not been precisely determined due to certain ongoing decommissioning activities at the site. The contribution of this source of gamma radiation will be evaluated and appropriately accounted in the design of the final status surveys in adjacent areas. However, some land area surrounding the ISFSI will exhibit a gamma radiation field that will be above the criteria for performing an FSS while the fuel is stored onsite. This portion of the site will not be released or surveyed until the fuel is removed from the site.

5.4.5 Area Preparation: Isolation and Control

5.4.5.1 Area Preparation

Before final status survey activities can begin in an area, a transition must occur where planned decommissioning activities are completed and the area is subsequently assessed to scope the required isolation and control measures. This includes establishing if the area is ready for final survey activities and identifying any work practice issues that must be addressed in survey planning and design. Determination of readiness for final status survey will be based on characterization and/or remediation surveys indicating that the residual radioactive material is likely to comply with the DCGLs and the removable contamination is below 1000 dpm/100 cm^2 (beta-gamma). Following this assessment, isolation and control measures will be implemented to prevent the introduction of plant-related contamination to soils or structures in the area, prior to, during and after final survey activities. These control measures will include posting (e.g., with a placard or sign) areas that have been turned over for final status survey. Isolation and control measures are implemented for areas such as an entire building or large, open areas, for which there should not be any impact from on-going decommissioning activities. In the event that additional remediation is required in an area following the implementation of isolation and control measures, local contamination control measures such as tents, HEPA filters, or vacuums will be employed as appropriate.

Prior to transitioning an area from decommissioning activities to isolation and control, a walkdown may be performed to identify access requirements and to specify the required isolation and control measures. The physical condition of the area will also be assessed, with any conditions that could interfere with final survey activities identified and addressed. If any support equipment needed for final survey activities, such as ladders or scaffolding, are in place, it will be evaluated to ensure that it does not pose the potential for introducing radioactive material into the area. Industrial safety and work practice issues, such as access to high areas or confined spaces, will also be identified during the pre-survey evaluation. Operational health physics or decontamination support data, if available, will be reviewed to identify any potential areas where additional decontamination may be required prior to commencing final survey activities. In some instances, turnover surveys may be performed to verify that an area is ready for final survey.

The following criteria must be met for an area to be deemed ready for isolation and control:

- planned decommissioning activities, in support of license termination, in the area are complete;

- planned decommissioning activities, in support of license termination, in areas either adjacent to the area to be isolated or that could otherwise affect it are either complete or are deemed not to have any reasonable potential to spread plant-related radioactive material to the area;

- tools and equipment, which are not needed for final survey activities and could interfere with final survey activities, are removed;

- equipment to be used for final survey activities is evaluated to ensure it does not pose the potential for introducing plant-related radioactive material into the area; and

- where practical, transit paths to or through the area, except those required to support final survey activities, are eliminated or re-routed.

Once the area meets the isolation and control criteria, isolation and control will be achieved through:

- a combination of personnel training, physical barriers and postings, and site notices as appropriate, to prevent unauthorized access to an isolated area;

- implementation of provisions to prevent the introduction of plant-related radioactive material by persons authorized to enter the area; and

- measures to prevent the introduction of plant-related radioactive material through the air or through other paths, such as systems or piping.

For buildings, measures to prevent against the introduction of plant-related radioactive material by persons entering an isolated area may include personnel frisking stations at the entry point, the use of "sticky pads," or other such routine methods. Isolation from airborne material may include sealing off openings, including doors and ventilation ducts. Though not likely to be encountered, if a potential for waterborne material is deemed to exist (e.g., floor drains or penetrations left by decommissioning activities), similar measures will be taken to be sure such sources are sealed off from the isolated area. In addition to these physical controls, access points to buildings will be posted with signs that include information pertaining to the proper individual to contact prior to conducting plant-related activities in the area. An administrative process will be used to evaluate, approve (or deny), and document plant related activities conducted in these open land areas during and following Final Status Surveys.

For open land areas, access roads and trails will be posted with signs that include information pertaining to the proper individual to contact prior to conducting plant-related activities in the area. An administrative process will be used to evaluate, approve (or deny), and document plant related activities conducted in these open land areas during and following Final Status Surveys. For land areas that do not have positive access control (i.e., areas that have passed FSS but are not surrounded by a fence), the area will be inspected annually and any material that has been deposited since the last inspection will be investigated (i.e., scanned and/or sampled).

5.4.5.2 Area Surveillance Following Final Status Surveys

Isolation and control measures will be implemented through approved plant procedures and will remain in force throughout final survey activities and until there is minimal risk of recontamination from decommissioning or the survey area has been released from the license. In the event that isolation and control measures established for a given survey unit are compromised, evaluations will be performed and documented to confirm that no radioactive material was introduced into the area that would affect the results of the Final Status Survey.

To provide additional assurance that land areas and structures that have undergone successful final status surveys (FSS) remain unchanged until final site release, these areas will be surveyed periodically. The strategy for performing these surveys depends on the following:

- the type of area (land or building),
- the area classification of the survey areas as well as that of the adjacent survey areas,
- the potential for re-contamination of the area from remediation activities in adjacent areas,
- the proximity to operational events involving radioactive contamination.

For FSS areas adjacent to areas where remediation activities (as required to meet the site release criteria) or where operational events may have impacted the FSS area, a re-survey of the FSS area will be conducted. This re-survey will involve judgmental sampling of boundary and/or potential access points to the FSS area. If the results of the re-surveys indicate that contamination is statistically greater than the initial FSS results (that is, where the re-survey mean > 2 standard deviations from the initial FSS mean), then an investigation survey will be conducted of the area. The investigation survey will include a larger physical area than the re-survey. If the results of the investigation survey are statistically different than the FSS survey results, then a full FSS survey of the affected units will be performed in accordance with the LTP. The results of re-surveys and investigation surveys will be documented and maintained in the FSS files for the affected survey units. Additionally, for any area that has completed FSS activities, any soil, sediment, or equipment relocated to that area will require demonstration that the material introduced does not result in residual radioactivity that is statistically different than that in the FSS.

Periodic surveys will be performed on a random sample basis for 5% of those survey areas for which FSS activities have been completed. If the results of these surveys exceed specific radiological contamination levels, an investigation survey will be conducted. This investigation survey will be more extensive than the scope of the routine survey to define the magnitude and extent of the contamination. If the results of the investigation survey indicate contamination that is statistically different than the FSS survey results (as described above), then full FSS of the affected survey areas will be performed in accordance with the LTP. The results of re-surveys and investigation surveys will be documented and maintained in the FSS files for the affected survey areas. These periodic surveys, and any follow-up actions, will continue until the FSS activities for all available survey areas have been successfully completed.

5.4.6 Selection of DCGLs

Residual levels of radioactive material that corresponds to allowable radiation dose standards are calculated by analysis of various pathways (direct radiation, inhalation, ingestion, etc.), media (concrete and soils) and scenarios through which exposures could occur. These derived levels, known as derived concentration guideline levels (DCGLs), are presented in terms of surface or mass activity concentrations. DCGLs usually refer to average levels of radiation or radioactivity above appropriate background levels. DCGLs applicable to building or other structural surfaces are expressed in units of activity per surface area (typically dpm/100 cm^2). When applied to soil, sediments or structural materials where the radionuclides are distributed throughout, DCGLs are expressed in units of activity per unit of mass (typically pCi/g).

Section 6 of this plan describes in detail the modeling performed to develop the radionuclide-specific DCGLs for soil, building surfaces and volumetrically-contaminated concrete. These values will be used to establish DCGLs for survey units in cases where measurements are made that are not radionuclide specific or when difficult-to-measure radionuclides are present that necessitate the need for a surrogate radionuclide. In such cases, DCGLs will be established based on a representative radionuclide mix established for each survey unit. In cases where measurable activity still exists, it is expected that the radionuclide mix will be established based on gamma-ray spectroscopy and alpha spectroscopy (where conditions warrant) or equivalent analyses on representative samples, with scaling factors used to establish the activity contribution for any difficult-to-measure radionuclides that might be present. Scaling factors will be selected from available composite waste stream analyses or similar assays. Such analyses are performed periodically and documented in support of waste characterization needs.

In the case of survey units for which there is not measurable activity distinguishable from background at the time of FSS design, a representative radionuclide mix (e.g., relative concentration of radionuclides) will be selected based upon historical characterization information from that survey unit or from a unit with a similar history and physical characteristics (e.g., adjacent areas). This representative mix may be used to determine a gross activity DCGL or surrogate ratio DCGL, and to determine the MDC and the number of sample points. Alternatively, a conservative DCGL could be selected as the basis for FSS activities.

5.4.6.1 Gross Activity DCGLs

For alpha or beta surface activity measurements, field measurements will typically consist of gross activity assessments rather than radionuclide-specific techniques. Gross activity DCGLs will be established, based on the representative radionuclide mix, as follows:

$$DCGL_{GA} = \frac{1}{\sum_{1}^{n} \frac{f_i}{DCGL_i}} \qquad \text{(Equation 5-1)}$$

where

f_i = fraction of the total activity contributed by radionuclide i
n = the number of radionuclides
$DCGL_i$ = DCGL for measurable radionuclide i

Gross activity DCGLs can be developed for gross beta measurements, or a gross beta DCGL can be scaled so that it acts as a surrogate for gross alpha (see Section 5.4.6.2). Equation 5-1 will be applied for radionuclides that are present in a survey unit in concentrations greater than 5% of their respective DCGL. The aggregate of all radionuclides not included in the gross activity DCGL, based on the percentage of their respective DCGL, will not exceed 10%. This practice is conservative relative to the process presented in 10CFR20 in which radionuclides that contribute less than 10% to dose, provided the aggregate does not exceed 30%, are not required to be included in the dose assessment.

5.4.6.2 Surrogate Ratio DCGLs

In order to address the potential for contamination with difficult-to-detect radionuclides for gross surface contamination measurements, one of two processes will be employed: (1) the use of a surrogate relationship to contamination or (2) direct measurement of alpha contamination. It is acceptable industry practice to make measurements to assay a difficult-to-detect radionuclide by using a surrogate measurement for an easier-to-detect radionuclide. A common example would be to assay an alpha emitting radionuclide by making a beta measurement. In such cases, in order to demonstrate compliance with the release criterion for a given survey unit, the DCGL for the surrogate radionuclide or mix of radionuclides must be scaled to account for the fact it is being used as an indicator for an additional radionuclide or mix of radionuclides. The result is referred to as a surrogate DCGL.

The surrogate DCGL is computed based on the activity ratio between a difficult-to-detect radionuclide(s) and the easy-to-measure radionuclide(s). The surrogate DCGL is computed as:

$$DCGL_{surrogate} = DCGL_{ETD} \times \frac{DCGL_{DTD}}{\left(f_{DTD:ETD} \times DCGL_{ETD}\right) + DCGL_{DTD}} \qquad \text{(Equation 5-2)}$$

where

$DCGL_{ETD}$ = the DCGL for the easy-to-detect radionuclide;
$DCGL_{DTD}$ = the DCGL for the difficult-to-detect radionuclide; and
$f_{DTD:ETD}$ = the activity ratio of the difficult-to-detect radionuclide to the easy-to-detect radionuclide.

Equation 5-2 will be applied for radionuclides that are present in a survey unit in concentrations greater than 5% of their respective DCGL. The aggregate of all radionuclides not included in the gross activity DCGL, based on the percentage of their respective DCGL, will not exceed 10%.

5.4.6.3 Elevated Measurement Comparison (EMC) DCGLs

The DCGL established for the average residual contamination in a survey unit is $DCGL_W$. Values of the $DCGL_W$ may be scaled through the use of area factors to obtain a DCGL that represents the same dose to an individual from residual contamination over a smaller area within a survey unit. Such a value is called $DCGL_{EMC}$, where the subscript EMC stands for elevated measurement comparison. The $DCGL_{EMC}$ is defined as the product of the applicable $DCGL_W$ and a correction factor know as the area factor.

The area factor is equal to the ratio of the dose from the base-case contaminated area to the dose from a smaller contaminated area with the same radioactive source concentration. Area factors are required for both the resident farmer and the building occupancy scenarios. Area factors for both the resident farmer and building occupancy scenarios are being calculated for the radionuclides of concern at the YNPS site considering all applicable potential pathways of exposure.

For the resident farmer scenario, RESRAD (Version 6.21) is being used to determine area factors. For the building occupancy scenario, RESRAD-BUILD (Version 3.21) is being used to determine area factors. Area factors are not being computed for areas smaller than 1 m^2 for either the resident farmer or the building occupancy scenarios. Area factors are being provided in an appendix to Section 6 of the LTP.

5.5 Final Status Survey Design

The general approach prescribed by MARSSIM for final status surveys requires that at least some minimum number of measurements or samples be taken within a survey unit, so that the non-parametric statistical tests used for data assessment can be applied with adequate confidence. Decisions regarding whether a given survey unit meets the applicable release criterion are made based on the results of these tests. Scanning measurements are used to check the design basis for the survey by evaluating if any small areas of elevated activity exist that would require re-classification, tighter grid spacing for the fixed measurements, or both. However, MARSSIM also recognizes that alternatives to this general approach for final status surveys exist. Specifically, MARSSIM states that if the equipment and methodology used for scanning are capable of providing data of the same quality as fixed measurements (e.g., detection limit, location of measurements, ability to record and document results), then scanning may be used in place of fixed measurements, provided that results are documented for at least the number of locations that would have been necessary had fixed measurements been used.

Final status surveys for the YNPS surface soils and structures will be designed, following MARSSIM guidance, using combinations of fixed measurements, traditional scanning surveys, and other advanced survey methods, as appropriate, to evaluate survey units relative to their applicable release criteria. As MARSSIM does not directly address final status survey for subsurface soils, the principles of MARSSIM will guide the design of these surveys. Subsurface survey considerations can be found in Section 5.6.3.2.2.

Under MARSSIM, the level of survey effort required for a given survey unit is determined by the potential for contamination as indicated by its classification. Class 3 survey units receive judgmental scanning and randomly located measurements or samples. Class 2 survey units receive scanning over a portion of the survey unit based on the potential for contamination, combined with fixed measurements or sampling performed on a systematic grid. Class 1 survey units receive scanning over 100% of the survey unit combined with fixed measurements or sampling performed on a systematic grid. Depending on the sensitivity of the scanning method, the grid spacing may need to be adjusted to ensure that small areas of elevated activity are detected.

For combinations of fixed measurements and traditional scanning, MARSSIM methodology is to select a requisite number of measurement locations to satisfy the decision error rates for the non-parametric statistical test to be used for data evaluation and to account for sample losses or data anomalies. The purpose of scans is to confirm that the area was properly classified and that any small areas of elevated activity are within acceptable levels (i.e., are less than the applicable $DCGL_{EMC}$). Depending on the sensitivity of the scanning method used, the number of fixed measurement locations may need to be increased so the spacing between measurements is reduced. Details on selecting the number and location of fixed measurements are the subject of Section 5.5.1 and subsequent subsections of this plan. The coverage requirements that will be applied for scans performed in support of final status surveys for the YNPS site are:

- For Class 1 survey units, 100% of the surface will be scanned;

- For Class 2 survey units, between 10% and 100% of the surface will be scanned in a combination of systematic and judgmental measurements for outdoor units and for floor and lower walls of structures; and 10% to 50% of the surface will be covered for upper walls and ceilings;

- Scanning will be done on a judgmental basis for Class 3 survey units.

Though the emphasis of the document is on conducting final status surveys through a combination of fixed measurements and scans, MARSSIM also allows for use of advanced survey technologies as long as these techniques meet the applicable requirements for data quality and quantity. "Advanced technologies" in this context refers to survey techniques where the instrument is capable of recording data as an area is surveyed and the measurement sensitivity is an acceptable fraction of the applicable $DCGL_W$ (see Section 5.6.1.3). Such methods are desirable for final status surveys since they allow survey units to be assessed with a single measurement rather than separate fixed measurements and scans.

Advanced survey techniques may be used alone or in combination with fixed measurements and scans to assess a survey unit. For Class 1 and Class 2 units, two conditions must be met for advanced technologies to be employed as the only survey technique: an acceptable fraction of the survey unit surface area must be scanned; and the minimum detectable concentration (MDC) for the measurements must be an acceptable fraction of the $DCGL_W$. For Class 1 units, 100% of the area must be covered. For Class 2 units, the coverage requirements for advanced technologies to be used alone are from 50% to 100% of the area for outdoor survey units or for floors and lower walls; and from 10% to 50% of the area for upper walls and ceilings. In cases where these coverage requirements cannot be achieved by an advanced survey technology or where the MDC is too large relative to the applicable $DCGL_W$ (see below), the survey will be augmented with fixed measurements and traditional scans as necessary in accordance with Section 5.5.1 and subsequent subsections of this plan. Advanced technologies may be used for judgmental assessments in Class 3 areas as long as the following MDC requirements are met.

For fixed measurements, MARSSIM states that MDCs should be as far below the $DCGL_W$ as possible, with values less than 10% of the $DCGL_W$ being preferred, and up to 50% of the $DCGL_W$ being acceptable. These same criteria will be used when deciding if advanced survey techniques can be used in place of fixed measurements and traditional scans for a given survey unit. MDCs for advanced techniques will be computed using background count rates obtained using appropriate reference materials.

With respect to the survey methods and techniques discussed above, the survey design criteria that will be employed for final status surveys for the YNPS site are summarized below. Note that "fixed measurements" is used interchangeably to refer to measurements or samples taken at specific locations.

- For Class 1 or Class 2 survey units, advanced survey technologies may be used exclusively only in survey units for which for which the above coverage requirements can be achieved and MDCs are no greater than 50% of the applicable $DCGL_W$.

- For Class 1 or Class 2 survey units for which advanced technologies would have an acceptable MDC, but the above coverage requirements cannot be achieved, advanced technologies may be used over 100% of the accessible area with a combination of fixed measurements and traditional scans used over the remainder of the area as specified in Section 5.5.1 and subsequent subsections of this plan.

For any survey units for which advanced survey techniques are impractical, fixed measurements and traditional scans will be used exclusively in accordance with this plan.

5.5.1 Selecting the Number of Fixed Measurements and Locations

The MARSSIM methodology for evaluating whether a survey unit meets its applicable release criterion using fixed measurements plus scans is based on using non-parametric statistical tests for data assessment. Specifically, the methods of MARSSIM are based on two non-parametric tests: the Wilcoxon Rank Sum (WRS) test and the Sign test, as discussed in Section 5.7. Selection of the required minimum number of data points depends on which statistical test is going to be used to evaluate the data, and thus depends on what type of measurements are to be made (gross measurement, net measurement or radionuclide specific) and if the radionuclide(s) of interest appear(s) in background.

5.5.1.1 Establishing Acceptable Decision Error Rates

One input to the process of selecting the required number of data points for a given survey, which does not depend on the statistical test applied, is the selection of the acceptable decision error rates. Decision errors refer to making false decisions by either rejecting a null hypothesis when it is true (a Type I error) or accepting a null hypothesis when it is false (a Type II error). With respect to final status surveys, the null hypothesis is that the survey unit of interest contains residual contamination in excess of the applicable release criterion. Thus, a Type I error refers to concluding that an area meets the release criteria when in fact it does not. The probability of making a Type I error is referred to as alpha (α). Likewise, a Type II error refers to concluding a unit does not meet the release criteria when it actually does. The probability of making a Type II error is denoted beta (β). Selecting values of α that are too low will result in an excessive number of fixed measurements being required. Likewise, selecting a β value that is too large can result in excessive costs in that survey units that meet the release criterion could be subjected to superfluous remediation efforts. Under the current regulatory models, an α value that is too large equates to greater risk to the public in that there is a greater chance of releasing a survey unit that does not meet the release criterion.

Section A.7.2 of Appendix A to NUREG-1757 recommends that the α decision error rate be set to 0.05 (5%) and that "any value of β is acceptable to the NRC." Thus, decision error rates for final status surveys designed for the YNPS site will be set as follows:

- the α value will always be set to 0.05 unless prior NRC approval is granted for using a less restrictive value;

- the β value is nominally set to 0.05, but may be changed if it is found that more fixed measurements than necessary are being made to demonstrate compliance with the release criterion.

5.5.1.2 Determining the Relative Shift

Another input to the process of selecting the required number of measurements that is somewhat independent of the statistical test to be employed is the determination of what is called the relative shift. The relative shift is a parameter that quantifies the concentrations to be measured in a survey unit relative to the variability in these measurements. The relative shift is a function of the $DCGL_W$, a parameter called the "lower bound of the gray region" (LBGR), and either the expected standard deviation of the measurements to be made in the survey unit (σ_s) or the standard deviation established for the corresponding reference area (σ_r). The choice of σ_s or σ_r depends on whether the survey data are to be evaluated against a reference area(s). Reference areas are used if the WRS test is applied or, where gross measurements are to be background subtracted, the Sign test may be used. The σ_s values will be selected by:

- using existing characterization or remediation support survey data or
- making preliminary measurements.

Values of σ_r will be computed using data collected from measurements in reference areas or from reference materials, as appropriate.

Given that σ_s and σ_r values should reflect a combination of the spatial variability in the concentration and the precision in the method of measurement, these values will be selected based on existing survey data only when the existing measurements were made using techniques equivalent to those to be used during the final status survey.

The LBGR represents the concentration to which the survey unit must be decontaminated in order to have an acceptable probability of passing the statistical test. The difference between the $DCGL_W$ and the LBGR, known as the shift, can be thought of as a measure of the resolution of the measurements that will be made in a survey unit. The shift is denoted as Δ.

The relative shift (Δ/σ) is computed as the quotient of the shift and the appropriate standard deviation values. If no reference area data are needed to evaluate the survey results, the expected standard deviation of the measurements (σ_s) is used. If a reference area is required, the larger of the values of σ_s or σ_r is used.

To compute the relative shift, the appropriate sigma value and an initial LBGR are selected. The initial value for LBGR will be based upon site specific information, if available; otherwise, per MARSSIM, and Section A.7.1 of Appendix A to NUREG-1757, the initial value for the LBGR will be set to one-half of the $DCGL_W$. If the resulting relative shift is not in the range of 1.0 and 3.0, the LBGR is adjusted until it is. If the relative shift is too low, the LBGR is decreased; and if the relative shift is too high, the LBGR is increased.

5.5.1.3 Selecting the Required Number of Measurements for the WRS Test

The minimum number of fixed measurements required when the WRS is computed by the following equation:

$$N = \frac{1}{2} \times \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2} \qquad \text{(Equation 5-3)}$$

where

N = the minimum number of measurements required for each survey area or reference area;
$Z_{1-\alpha}$ = the percentile represented by the α decision error;
$Z_{1-\beta}$ = the percentile represented by the β decision error; and
P_r = the probability that a random measurement from the survey unit exceeds a random measurement from the reference area by less than the $DCGL_W$ when the survey unit median is equal to the LBGR concentration above background.

Values of P_r, $Z_{1-\alpha}$ and $Z_{1-\beta}$ will be taken from Tables 5.1 and 5.2 of MARSSIM. P_r is a function of the relative shift, and $Z_{1-\alpha}$ and $Z_{1-\beta}$ depend on the selected values for α and β.

The value of N computed for the WRS test applies for both the survey unit and the reference area (i.e., at least N measurements should be performed in both areas). To ensure against lost or unusable data, the value of N will be increased by at least a factor of 1.2 when assigning the number of measurements to be made.

5.5.1.4 Selecting the Required Number of Measurements for the Sign Test

The minimum number of fixed measurements required when the Sign test is computed by the following equation:

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{4\left(Sign\ p - 0.5\right)^2} \qquad \text{(Equation 5-4)}$$

where

N = the minimum number of measurements required;
$Z_{1-\alpha}$ = the percentile represented by the α decision error;
$Z_{1-\beta}$ = the percentile represented by the β decision error; and
Sign p = the probability that a random measurement from the survey unit will be less than the $DCGL_W$ when the survey unit median concentration is equal to the LBGR.

Values for Sign p will be taken from Table 5-4 of MARSSIM.

To ensure against lost or unusable data, the number of date points will be will be increased by 20%, and rounded up, over the value, N, calculated in Equation 5-3 and 5-4.

5.5.1.5 Assessing the Need for Additional Measurements in Class 1 Survey Units

Given the potential for small areas of elevated activity in Class 1 survey units, evaluations must be performed to assess the potential for missing such areas while scanning in locations not covered by fixed measurements. This evaluation, referred to as the Elevated Measurement Comparison (EMC), is performed by comparing the MDC of the scanning technique to the $DCGL_{EMC}$ for the survey unit of interest. If the scanning MDC is larger than the $DCGL_{EMC}$, additional measurements may be required beyond the minimum number computed via Equation 5-3 or 5-4. The effect of these additional measurement points is to tighten the grid spacing for the fixed measurements, thus reducing the probability of missing a small area of elevated activity to an acceptable level.

The adequacy of the scanning technique will be evaluated by calculating a scanning MDC, expressed as a fraction of the $DCGL_{EMC}$ as shown below.

As described in Section 5.4.6.3, the relationship between the $DCGL_{EMC}$ and the $DCGL_W$ using the area factor for nuclide i is:

$$DCGL^i_{EMC} = AF^i DCGL^i_W \qquad \text{(Equation 5-5)}$$

Where, AF^i is the area factor for radionuclide i.

For soil, the relationship between a scanning minimum detectable count rate (MDCR) and the minimum detectable soil concentration is:

$$MDC^i(pCi/g) = \frac{MDCR(cpm)}{E^i(cpm/pCi/g)} \qquad \text{(Equation 5-6)}$$

Where, E^i is the conversion factor (in cpm/pCi/g) for the radionuclide i (instrument efficiency for scanning)

The soil scanning MDC expressed as a fraction of the $DCGL_{EMC}$ is calculated by the following equation:

$$MDC(fDCGL_{EMC}) = MDCR\sum\frac{f^i}{E^i DCGL^i_{EMC}} = MDCR\sum\frac{f^i}{E^i AF^i DCGL^i_W} \qquad \text{(Equation 5-7)}$$

Where f^i is the decimal fraction of the radionuclide mix comprised by radionuclide i and is based upon characterization data, as a part of the Final Status Survey.

An example calculation to determine the soil scanning MDC expressed as a fraction of the $DCGL_{EMC}$ when multiple radionuclides are present is shown below:

Assumptions:
Two radionuclides are present; Cs-137 and Co-60
Cs-137 fraction in mix (f) = 0.75
Co-60 fraction in mix (f) = 0.25
Cs-137 efficiency (E) = 228 cpm/pCi/g
Co-60 efficiency (E) = 882 cpm/pCi/g
Elevated area = 100 m^2
Example Cs-137 area factor (AF) = 2.93
Example Co-60 area factor (AF) = 1.41
Example Cs-137 $DCGL_W$ = 7.91 pCi/g
Example Co-60 $DCGL_W$ = 3.81 pCi/g
MDCR = 2,000 cpm

$$MDC(fDCGL_{EMC}) = 2{,}000\left[\frac{0.75}{(228)(2.93)(7.91)} + \frac{0.25}{(882)(1.41)(3.81)}\right] = 0.4$$

For scanning building surfaces, the following equation from MARSSIM provides the method to calculate the MDC for beta-gamma measurements. It has been repeated here below for clarity:

$$MDC(dpm/100cm^2) = \frac{1.38\sqrt{B}}{\sqrt{p}\,e_i e_s \left(\frac{A}{100}\right)t} \qquad \text{(Equation 5-8)}$$

1.38 = sensitivity index,
B = number of background counts in time interval t,
p = surveyor efficiency,
ε_i = instrument efficiency for the emitted radiation (counts per emission),
ε_s = source efficiency (intensity) in emissions per disintegration,
A = sensitive area of the detector (cm^2),
t = time interval of the observation while the probe passes over the source (min)

With t is the time the detector spends over a source of radionuclide i which can be related to the travel velocity of the probe, V(cm/min), and the minimum dimension of the detector, L (cm), as:

$$t(\min) = \frac{L(cm)}{V(cm/\min)} \qquad \text{(Equation 5-9)}$$

Equation 5-8 can be rewritten as follows:

$$MDC^{i}(dpm/100cm^{2}) = \frac{1.38\sqrt{\frac{B}{t^{2}}}}{\sqrt{p}e_{i}^{i}e_{s}^{i}\left(\frac{A}{100}\right)} = \frac{1.38\sqrt{\frac{R_{b}}{t}}}{\sqrt{p}e_{i}^{i}e_{s}^{i}\left(\frac{A}{100}\right)} = \frac{1.38\sqrt{R_{b}}}{\sqrt{p}\sqrt{t}e_{i}^{i}e_{s}^{i}\left(\frac{A}{100}\right)} \qquad \text{(Equation 5-10)}$$

Substituting Equation 5-9 into 5-10 gives:

$$MDC^{i}(dpm/100cm^{2}) = \frac{1.38\sqrt{R_{b}}}{\sqrt{p}e_{i}^{i}e_{s}^{i}\left(\frac{A}{100}\right)\sqrt{\frac{L}{V}}} \qquad \text{(Equation 5-11)}$$

The MDCR for an analog detector with an audible signal can be expressed as:

$$MDCR(cpm) = \frac{1.38\sqrt{B}}{t} = \frac{1.38\sqrt{R_{b}}}{\sqrt{t}} = \frac{1.38\sqrt{R_{b}}}{\sqrt{\frac{L}{V}}} \qquad \text{(Equation 5-12)}$$

Using this, Equation 5-11 is re-written as:

$$MDC^{i}(dpm/100cm^{2}) = \frac{MDCR}{e_{i}^{i}e_{s}^{i}\left(\frac{A}{100}\right)\sqrt{p}} \qquad \text{(Equation 5-13)}$$

To allow for multiple radionuclides, the scan MDC expressed as a fraction of the $DCGL_{EMC}$ is:

$$MDC(fDCGL_{EMC}) = \frac{MDCR}{\left(\frac{A}{100}\right)\sqrt{p}} \sum \frac{f^i}{e_i^i e_s^i DCGL_{EMC}^i} \qquad \text{(Equation 5-14)}$$

By substituting $DCGL_{EMC}^i = AF^i DCGL_W^i$ into Equation 5-14 yields the building surface scanning MDC equation expressed as a fraction of the $DCGL_{EMC}$:

$$MDC(fDCGL_{EMC}) = \frac{MDCR}{\left(\frac{A}{100}\right)\sqrt{p}} \sum \frac{f^i}{e_i^i e_s^i AF^i DCGL_W^i} \qquad \text{(Equation 5-15)}$$

If YAEC intends to use a method of calculating MDC, different than that in MARSSIM as presented above, a technical evaluation of the method will be written. This evaluation will be available for NRC inspection in support of final status survey activities.

An example calculation to determine the building surface scanning MDC expressed as a fraction of the $DCGL_{EMC}$ when multiple radionuclides are present is shown below:

Assumptions:
Two radionuclides are present; Cs-137 and Co-60
Cs-137 fraction in mix (f) = 0.75
Co-60 fraction in mix (f) = 0.25
Probe width (L) = 10.2 cm (4 inches)
Scan rate (V) = 305 cm/min (2 inches/sec)
Background count rate (R_b) = 200 cpm
p = 0.5
ε_i = 0.3 for Co-60
ε_i = 0.38 for Cs-137
ε_s = 0.25 for Co-60
ε_s = 0.5 for Cs-137
Probe area (A) = 100 cm^2
MDCR = 27.6 cpm
Elevated area = 10 m^2
Example Cs-137 area factor (AF) = 2.6
Example Co-60 area factor (AF) = 2.5
Example Cs-137 $DCGL_W$ = 4.30E+04 dpm/100 cm^2
Example Co-60 $DCGL_W$ = 1.11E+04 dpm/100 cm^2

$$MDC(fDCGL_{EMC}) = \frac{27.6}{\left(\frac{100}{100}\right)\sqrt{\frac{10.2}{305}}}\left[\frac{0.75}{(0.38)(0.5)(2.6)(4.30E4)} + \frac{0.25}{(0.3)(0.25)(2.5)(1.11E4)}\right] = 0.02$$

As shown in these two examples, the fraction of $DCGL_{EMC}$ is less than one. Therefore no additional measurements are required.

If the value of MDC ($fDCGL_{EMC}$) is greater than one, additional measurements may need to be taken in the survey unit as determined by taking the following steps.

Determine the size of the elevated area from the area factors corresponding to the highest $fDCGL_{EMC}$ which is still less than one. That area is denoted as A_{EMC}.

The number of measurements (N_{EMC}) required to detect an area of elevated concentration equal to A_{EMC} is then computed as

$$N_{EMC} = \frac{A}{A_{EMC}} \qquad \text{(Equation 5-16)}$$

where A is the total area of the survey unit. N_{EMC} (computed via Equation 5-16) is then compared to N, the number of fixed measurement points computed via Equation 5-3 or 5-4. The larger of N_{EMC} or N is then used as the requisite number of fixed measurement locations and to compute the grid spacing.

5.5.1.6 Determining Measurement Locations

For Class 1 and Class 2 survey units, fixed measurements will be performed over a systematic measurement pattern consisting of a grid having either a triangular or a square pitch. The pitch (grid spacing) will be determined based on the number of measurement required and whether the desired grid is triangular or square.

Systematic grids will not be used for surveys involving fixed measurements for Class 3 units. Instead, fixed measurement locations will be selected at random throughout the survey unit area by generating pairs of random numbers between zero and one. One pair of random numbers will be generated for each fixed measurement to be made. The random number pairs, representing (x, y) coordinates, will be multiplied by the maximum length and width dimensions of the survey unit to yield the location for each fixed measurement. For odd-shaped survey units, a rectangular area encompassing the survey unit will be used to establish the maximum length and width. A new pair of random numbers will be generated if any of them give locations that are not actually within the survey unit boundaries. New pairs of numbers will also be generated in cases where a measurement cannot be made at a specific location because of an obstruction, inaccessibility, etc.

The spacing to be used in setting up the systematic grid used to establish fixed measurement locations for Class 1 and Class 2 areas will be computed as

$$L = \sqrt{\frac{A}{0.866N}} \quad \text{for a triangular grid, or} \qquad \text{(Equation 5-17)}$$

$$L = \sqrt{\frac{A}{N}} \quad \text{for a square grid} \qquad \text{(Equation 5-18)}$$

where L = grid spacing (dimension is square root of the area),
A = the total area of the survey unit, and
N = the desired number of measurements.

In the case of Class 1 units, the value used for N in Equations 5-17 and 5-18 should be the larger of that from Equations 5-3 or 5-4 (if the scan MDC is sufficient to see small areas of elevated activity) or Equation 5-16. The value of N should include additional measurements required to ensure against losses or unusable data.

Once the grid spacing is established, a random starting point will be established for the survey pattern using the same method as described above for selecting random locations for Class 3 units. Starting from this randomly-selected location, a row of points will then be established parallel to one of the survey unit axes at intervals of L. Additional rows will then be added parallel to the first row. For a triangular grid, additional rows will be added at a spacing of 0.866L from the first row, with points on alternate rows spaced mid-way between the points from the previous row. For a square grid, points and rows will be spaced at intervals of L. Section 5.5.2.5 of MARSSIM describes the process to be used for selecting fixed measurement locations and provides examples of how to establish both a systematic grid and random measurement locations.

Software tools that accomplish the necessary grid spacing, including random starting points and triangular or square pitch, may be employed during Final Status Survey. When available, this software will be used with suitable mapping programs to determine coordinates for a global positioning system (GPS). The use of these tools will provide a reliable process for determining, locating and mapping measurement locations in open land areas separated by large distances and will be helpful during independent verification.

5.5.2 Judgmental Assessments

For those Class 2 and Class 3 survey units for which 100% of the area is not surveyed, it is important to consider performing judgmental assessments to augment any regimented measurements made in accordance with the above guidance. Such assessments may consist of biased sampling or measurements performed in locations selected on the basis of site knowledge and professional judgment. Judgmental assessments serve to provide added assurance that residual contamination at the site has been adequately located and characterized.

In addition to any judgmental measurements deemed necessary to provide comprehensive survey coverage for a given survey unit, the survey process should include an isotopic mix evaluation in cases where measurable activity still exists. Doing so will allow an assessment of the adequacy of the $DCGL_W$ selected for the survey unit in question to be made during the subsequent data assessment phase. For gross count measurements (i.e., not radionuclide specific), radionuclide mix information will also allow for an evaluation of the suitability of the efficiencies applied in converting raw count data to activity.

The basis for judgmental assessments will be documented in the Final Status Survey Plan.

5.5.3 Data Investigations

5.5.3.1 Investigation Levels

An important aspect of the final status survey is the selection and implementation of investigation levels. Investigation levels are levels of radioactivity used to indicate when additional investigations may be necessary. Investigation levels also serve as a quality control check to determine when a measurement process begins to deviate from expected norms. For example, a measurement that exceeds an investigation level may indicate a failing instrument or an improper measurement. However, in general, investigation levels are used to confirm that survey units have been properly classified.

When an investigation level is exceeded, the first step is to confirm that the initial measurement/sample actually exceeds the particular investigation level. Depending on the results of the investigation actions, the survey unit may subsequently require re-classification, remediation, and/or re-survey. Investigation levels are established for each class of survey unit. The investigation levels (criteria), to be employed for the YNPS final status survey effort, are given in Table 5-2.

Table 5-2
Investigation Levels

Survey Unit Classification	For fixed measurements or samples, perform investigation if:	For scan measurements, perform investigation if:
Class 1	$> DCGL_{EMC}$ or $> DCGL_W$ and a statistical outlier.	$> DCGL_{EMC}$
Class 2	$> DCGL_W$	$> DCGL_W$ or $> MDC_{scan}$ if MDC_{scan} is greater than the $DCGL_W$
Class 3	$> 0.5 \times DCGL_W$	Detectable over background.

For Class 1 survey units, measurements above the $DCGL_W$ are not necessarily unexpected. However, such a result may still indicate a need for further investigation if it is significantly different than the other measurements made within the same survey unit. Thus, some additional evaluation criterion is needed to assess if results from fixed measurements or samples in a Class 1 survey unit that exceed the $DCGL_W$ warrant further attention. Measurements in Class 1 survey units that exceed the $DCGL_W$ and differ from the mean of the remaining measurements by more than three standard deviations will therefore be investigated. Measurements in Class 1 units that exceed the $DCGL_W$, but do not differ from the mean by as much may still be investigated on the basis of professional judgment, as may any measurements that differ significantly from the rest of the measurements made within a given survey unit.

In Class 2 or Class 3 areas, neither measurements above the $DCGL_W$ nor areas of elevated activity are expected. Thus, any fixed measurements or sampling results that exceed the $DCGL_W$ in these areas will be investigated. In the case of Class 3 areas, where any residual radioactivity would be unexpected, fixed measurement or sample results that are greater than 0.5 x $DCGL_W$ will be investigated. Because the survey design for Class 2 and Class 3 survey units is not driven by the elevated measurement comparison, any indication of residual radioactivity in excess of the $DCGL_W$ during the scan of a Class 2 unit will warrant further investigation. For Class 3 units, any scan measurement that shows a positive indication over background will be investigated.

In cases where an advanced survey method is used instead of fixed measurements or samples, the investigation levels given in Table 5-2 for fixed measurements or samples will be applied with the exception of the statistical outlier test for measurements in Class 1 survey units. In cases where advanced survey methods are used as a means of traditional scanning, the investigation levels for scan measurements in Table 5-2 will be used.

5.5.3.2 Investigations

Locations where initial measurements give results that exceed an applicable investigation level will be identified for confirmatory measurements. If it is confirmed that residual activity exists in excess of the investigation level, additional measurements will be made to determine the extent of the area of elevated activity and to provide reasonable assurance that other areas of elevated activity do not exist. Potential sources of the elevated activity will be postulated and evaluated against the original classification of the survey unit and its associated characterization data. The possibility of the source of the elevated activity having affected other adjacent or nearby survey units will also be evaluated. Documentation will be compiled containing the results from the investigation surveys and showing any areas where residual activity was confirmed to be in excess of the investigation level. If residual activity in excess of the applicable investigation level is confirmed, the documentation will also address the potential source(s) of the activity and the impact this has on the original classification assigned to the survey unit. A decision will then be made regarding re-classification of the unit in whole or in part.

5.5.3.3 Remediation

"Remediation" in the context of the LTP is intended to mean activities performed to meet the criteria of 10CFR20, Subpart E. Activities to remove materials may be performed for other reasons, and thus are not considered to be "remediation." If during the time of Final Status Survey, any areas of residual activity found to be in excess of the $DCGL_{EMC,}$ they will be remediated to reduce the activity to acceptable levels. Areas of residual activity may also need to be remediated to meet the ALARA criterion. Remediation actions are discussed in Section 4 and documented as described in Section 5.8.

5.5.3.4 Re-classification

The decision to re-classify an area, or part of an area, is made following a review of the basis for the original classification, considering the evaluation process outlined in Section 5.5.3.2 (consistent with MARSSIM). This process includes sufficient additional measurements to confirm the residual contamination, determine the nature and extent of the contamination present, provide assurance that other areas of elevated activity do not exist within the survey unit, and evaluate the impact (if any) of the affected area on nearby survey units. The results of these measurements will be evaluated, and the area, or part of the area, will be re-classified and re-surveyed per Section 5.5.3.5 in a manner that is consistent with the process described in MARSSIM. Additionally, if required remediation actions are taken in the area, it will be re-surveyed per Section 5.5.3.5 in a manner that is consistent with the process described in MARSSIM. Re-classification of areas from a less to a more restrictive classification may be done without prior NRC approval; however, re-classification to a less restrictive classification would require NRC notification at least 14 days prior to implementation, consistent with the guidance in Appendix 2 to NUREG-1700, Revision 1.

5.5.3.5 Re-survey

If a survey unit is re-classified (in whole or in part), or if remediation is performed within a unit, then the areas affected are subject to re-survey. Any re-surveys will be designed and performed as specified in this plan based on the appropriate classification of the survey unit. That is, if a survey unit is re-classified or a new survey unit is created, the survey design will be based on the new classification.

For example, a Class 3 area that is subdivided due to the unexpected presence of radioactivity will be divided into at least two areas. One of these may remain as a Class 3 area while the other may be a Class 2 area. In order to maintain the survey design Type I and Type II decision error rates in the Class 3 area, additional measurements may be required to be performed at randomly selected locations until the required total number of measurements is met (see Section 5.5.1). The new sub-divided Class 2 survey area will then be surveyed using a new survey design. The Type I and II decision error rates used are documented in the final status survey report.

A Class 2 area that is subdivided due to the levels of radioactivity identified will be divided into at least two areas as well. In this case if the original survey design criteria has been satisfied, no additional action is required, otherwise the remaining Class 2 survey unit will be redesigned. The new sub-divided survey unit will be surveyed against a new survey design.

If remediation is required in only a small area of a Class 1 survey unit, any replacement measurements or samples required will be made within the remediated area at randomly selected locations following verification that the remediation activities did not affect the remainder of the unit. Re-survey will be required in any area of a survey unit affected by subsequent remediation activities.

5.6 Final Status Survey Implementation and Data Collection

The requirements and objectives outlined in this plan and the project QA plan will be incorporated into Standard Operating Procedures (SOPs). Procedures will govern the survey design process, survey performance and data assessment (decision making). The final status survey design will be carried out in accordance with the SOPs and the QA plan, resulting in the generation of raw data. The product of the survey design process is a survey package, which addresses various elements of the survey, including, but not limited to:

- maps of the survey area showing the survey unit(s) and measurement/sample locations, as appropriate;
- applicable DCGLs
- instrumentation to be used;
- types and quantities of measurements or samples to be made or collected;
- investigation criteria;
- QA/QC requirements (e.g., replicate measurements or samples);
- personnel training;
- applicable health and safety procedures;
- approved survey procedures; and
- applicable operating procedures.

An important element of the survey design process is establishing the DCGLs for the measurements to be made. The DCGLs will be determined as described in Section 5.4.6 based on characterization data for the survey unit(s) being considered. Isotopic mix, material backgrounds, and the variability of these will be considered. The detection limit requirements dictated by the DCGLs affect the selection of both the instrumentation to be used for a given survey and the survey method(s) to be employed (advanced survey methods, fixed measurements, sampling; or combinations thereof).

5.6.1 Survey Methods

The survey methods to be employed in the final status surveys will consist of combinations of advanced technologies, scanning, fixed measurements, sampling, and other methods as needed to meet the survey objectives. Additional methods may be used if such become available between the time this plan is adopted and the completion of final survey activities. However, any new technologies must still meet the applicable requirements of this plan. Note that in some cases, the same instrument may be used for more than one type of survey. For instance, a sodium-iodide (NaI) detector may be used in either a scanning mode or for fixed spectroscopic measurements.

5.6.1.1 Scanning

Scanning is the process by which the operator uses portable radiation detection instruments to detect the presence of radionuclides on a specific surface (i.e., ground, wall, floor, equipment). The term scanning survey is used to describe the process of moving portable radiation detectors across a surface with the intent of locating residual radioactivity. Investigation levels for scanning surveys are determined during survey planning to identify areas of elevated activity. Scanning surveys are performed to locate radiation anomalies indicating residual gross activity that may require further investigation or action. These investigation levels may be based on the $DCGL_W$ or the $DCGL_{EMC}$.

Table 5-3 gives the aerial coverage requirements when scanning is used with fixed measurements.

Table 5-3
Traditional Scanning Coverage Requirements

Survey Unit Classification	Required Scanning Coverage Fraction
Class 1	100%
Class 2	Outdoor areas, floors, or lower walls of buildings: 10% to 100% Upper walls or ceilings: 10% to 50%
Class 3	Judgmental

5.6.1.2 Fixed Measurements

Fixed measurements are taken by placing the instrument at the appropriate distance above the surface, taking a discrete measurement for a pre-determined time interval, and recording the reading. Fixed measurements may be collected at random locations in a survey unit or may be collected at systematic locations and supplement scanning surveys for the identification of small areas of elevated activity. Fixed measurements may also be collected at locations identified by scanning surveys as part of an investigation to determine the source of the elevated instrument response. Professional judgment may also be used to identify locations for fixed measurements to further define the areal extent of contamination. Locations for fixed measurements specified by a given survey design will be established as discussed in Section 5.5.

5.6.1.3 Advanced Technologies

In the context of the License Termination Plan, advanced technologies refer to survey instruments or methods that create a spatially-correlated log of the measurements made as the detector is passed over an area. This logging of the measurements allows quantitative assessments of activity levels to be made, thus serving the same role as fixed measurements.

Having the measurements logged allows statistical analyses to be made using a large number of samples, which provides for enhanced detection sensitivity relative to traditional scanning. The sensitivity achieved using advanced survey methods may, in some cases, be small enough relative to the $DCGL_W$ that the advanced method alone will allow a decision to be made as to whether a survey unit meets the release criterion without the need for additional fixed measurements. The fact that the instrument records every measurement made over the entire area it covers inherently addresses the issue of small areas of elevated activity. Average and maximum residual activity concentrations can be quantified over any area desired, allowing one to assess compliance with the applicable criteria ($DCGL_W$ or $DCGL_{EMC}$) by inspection.

If advanced technology instrumentation is selected for use, a technical support document will be developed which describes the technology to be used and how the technology meets the objectives of the survey. This document will be available for NRC inspection in support of final status survey activities.

5.6.1.4 Other Advanced Survey Technologies

Other instruments and methods that may be used for final status surveys include, but are not limited to, in situ gamma spectrometry, in situ object counting systems, and systems capable of traversing ducting or piping. Like the advanced technologies discussed above, these other methods may in some cases provide sufficient areal coverage so that augmenting the measurement with scanning is not necessary.

In situ gamma spectrometry is an established technique for assaying the average radionuclide concentration in large volumes of material. It has the advantage of being able to assess large areas with a single measurement. If desired, the detector's field of view can be reduced through collimation to allow assay of smaller areas.

In situ object counting refers to gamma spectrometry systems that include software capable of modeling photon transport in complex geometries for the purpose of estimating detector efficiencies. This eliminates the need for a calibration geometry representing the object to be counted.

5.6.1.5 Samples

Sampling is the process of collecting a portion of a medium as a representation of the locally remaining medium. The collected portion of the medium is then analyzed to determine the radionuclide concentration. Examples of materials that may be sampled include soil, sediments, concrete, paint, and groundwater.

Section 5.9, "Final Status Survey Quality Assurance and Quality Control Measures" addresses QA requirements for final status survey activities that apply to onsite and offsite laboratories employed to analyze samples as a part of the final status survey process. Performance of laboratories will be verified periodically by QA auditors. This verification will include reviews of personnel training, procedures and equipment operation.

Trained and qualified individuals will collect and control samples. Sampling activities will be performed under approved procedures. YAEC will use a sample tracking and control system to ensure sample integrity.

5.6.2 Survey Instrumentation

5.6.2.1 Instrument Selection

The selection and proper use of appropriate instruments for both fixed measurements and laboratory analyses is one of the most important factors in assuring that a survey accurately determines the radiological status of a survey unit and meets the survey objectives. The survey plan design must establish acceptable measurement techniques for scanning and direct measurements. The DQO process must include consideration as to the type of radiation, energy spectrum and spatial distribution of radioactivity as well as the characteristics of the medium to be surveyed (e.g., painted, scabbled, chemically decontaminated).

The particular capabilities of a radiation detector establish its potential for being used in conducting a specific type of survey based on the factors discussed above. Radiation survey parameters that will be needed for final survey purposes include surface activities and radionuclide concentrations in soil. To determine these parameters, both field measurements and laboratory analyses will be necessary. For certain radionuclides or radionuclide mixtures, both alpha and beta radiation may have to be measured. In addition to assessing average radiological conditions, the survey objectives must address identifying small areas of elevated activity.

Instruments must be stable and reliable under the environmental and physical conditions where they will be used, and their physical characteristics (size and weight) should be compatible with the intended application. This has been the case for typical radiation detection instrumentation used at YNPS for operational surveys as well as scoping and characterization surveys.

The radiation detectors to be used for final survey activities at the YNPS Plant can be divided into three general classes:

- gas-filled detectors,
- scintillation detectors, and
- solid-state detectors.

Gas-filled detectors include ionization chambers, proportional counters (both gas-flow and pressurized) and Geiger-Mueller (GM) detectors. Scintillation detectors include plastic scintillators, zinc-sulfide (ZnS) detectors and sodium-iodide (NaI) detectors. Solid-state detectors include both n-type and p-type intrinsic germanium detectors.

Finally, the DQO process must evaluate, depending on the type of radiation of interest, and on the application, the ability of instrumentation to measure levels that are less than the DCGL. In some cases instruments used for scanning may have detection limits that are greater than the $DCGL_W$. This is recognized by MARSSIM as an acceptable approach as long as the grid spacing (for Class 1 survey units) and investigation levels used are in accordance with Sections 5.5.1.5, 5.5.1.6 and 5.5.3.1, respectively, of this plan. The DQO process for instrument selection is performed in the planning phase for an FSS activity and is typically documented by a technical support document, which is referenced in the survey plan.

5.6.2.2 Calibration and Maintenance

Instrumentation used for measurements to demonstrate compliance with the radiological criterion for license termination at the YNPS Plant will be calibrated and maintained under approved plant procedures and the Yankee Decommissioning Quality Assurance Program (YDQAP) or vendor QA plan that satisfies the requirement of the YDQAP. Instruments will be calibrated for normal use under typical field conditions at the frequency specified by vendor instructions or by approved plant procedures (at least annually). Calibration standards will be traceable to the National Institute of Standards and Technology (NIST). If external vendors are used for instrument calibration or maintenance, these services must be approved and conducted under the YDQAP. Calibration records will be maintained as required by plant procedures and the YDQAP.

Instruments used to measure gross beta surface activity will be calibrated using radionuclides such as Tc-99, Co-60, or Cs-137 so as to represent the beta energies for the beta-emitting radionuclides that will be encountered during final survey activities. Likewise, if direct measurements are performed for alpha-emitting radionuclides, radionuclides such as Pu-239 or Th-230 will likely be used to calibrate instruments used to assess alpha surface activity so the alpha energies of the TRU radionuclides that may be encountered are adequately represented.

The DQO process must consider the field conditions the instrument will be used in to determine the affect and magnitude of variation from conditions established during calibration. These conditions might include source to detector geometry (including distance and solid angle), size and distribution of the source relative to the detector, and composition and condition of surface to be assessed. Most of these factors should have been determined during the instrument selection process. In some cases, instrument efficiencies may require modifications to account for surface conditions or coverings. Such modifications, if necessary, will be established using the information in Section 5 of NUREG-1507 and pertinent site characterization data. This will be performed during the planning process and documented by a technical support document and referenced in the survey plan. This technical support document will include the evaluation supporting instrument selection.

5.6.2.3 Response Checks

The DQO process determines the frequency of response checks, typically before issue and after an instrument has been used (typically at the end of the work day but in some cases this may be performed during an established break in activity, e.g., lunch). This additional check will expedite the identification of a potential problem before continued use in the field. Instrumentation will be response checked in accordance with plant procedures. If the instrument response does not fall within the established range, the instrument will be removed from use until the reason for the deviation can be resolved and acceptable response again demonstrated. If the instrument fails a post-survey source check, data collected during that time period with the instrument will be carefully reviewed and possibly adjusted or discarded, depending on the cause of the failure. In the event that data are discarded, the affected area will be re-surveyed.

5.6.2.4 MDC Calculations

The DQO process evaluates the ability of the instrument to measure radioactivity at levels below the applicable DCGL. This evaluation will be performed and documented by a technical support document and referenced by the survey plan. This evaluation may also be included with the technical support document discussed in Section 5.6.2.1 above.

Instrument detection limits are typically quantified in terms of their minimum detectable concentration, or MDC. The MDC is the concentration that a given instrument and measurement technique can be expected to detect 95% of the time under actual conditions of use.

Instruments and methods used for field measurements will be capable of meeting the investigation level in Table 5-2.

Before any measurements are performed, the instruments and techniques to be used must be shown to have sufficient detection capability relative to the applicable DCGLs. The detection capability of a given instrument and measurement technique is quantified by its MDC.

5.6.2.4.1 MDCs for Fixed Measurements

Per NUREG-1507, MDCs for fixed measurements are computed as

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{B}}{Kt} \qquad \text{(Equation 5-19)}$$

where 3 and 4.65 = constants as described in NUREG-1507;
B = background counts during the measurement time interval (t);
t = counting time; and
K = a proportionality constant that relates the detector response to the activity level in the sample being measured.

The proportionality constant K typically encompasses the detector efficiency, self-absorption factors and probe area corrections, as required. The dimensions of the counting interval "t" are consistent with those for the MDC and the proportionality constant K. Thus, "t" would be in minutes to compute an MDC in dpm/100 cm^2.

An example calculation to determine the MDC_{fixed} for the detection of Co-60 with a 100 cm^2 gas proportional detector is shown below.

Assumptions:
Background count rate = 200 cpm
t = 1 minute
B = 200 counts in the measurement time interval (t)
K = $\varepsilon_i\varepsilon_s$(A/100), where A = area of the detector in cm^2
ε_i = 0.38 counts per emission
ε_s = 0.25 (from ISO 7503-1) emissions per disintegration
A = 100 cm^2

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{200}}{(0.38)(0.25)(100/100)(1)} = 724 dpm/100cm^2$$

Actual values for ε_s will be selected from ISO 7503-1 or NUREG-1507 or empirically determined and documented prior to performing the final status survey.

5.6.2.4.2 MDCs for Beta-Gamma Scan Surveys for Structure Surfaces

As recommended in Section 5.1 of Appendix E to NUREG-1727, MDCs for surface scans for structure surfaces for beta and gamma emitters will be computed via

$$MDC_{structure,scan} = \frac{1.38\sqrt{B}}{\sqrt{p}e_i e_s\left(\frac{A}{100}\right)t} \text{ dpm/100cm}^2 \qquad \text{(Equation 5-20)}$$

where 1.38 = sensitivity index,
B = number of background counts in time interval t,
p = surveyor efficiency,
ε_i = instrument efficiency for the emitted radiation (counts per emission),
ε_s = source efficiency (intensity) in emissions per disintegration,
A = sensitive area of the detector (cm^2),
t = time interval of the observation while the probe passes over the source (minutes).

The value of 1.38 used for the sensitivity index corresponds to a 95% confidence level for detection of a concentration at the scanning MDC with a false positive rate of 60%. The numerator in Equation 5-20 represents the minimum detectable count rate that the observer would "see" at the performance level represented by the sensitivity index. The surveyor efficiency (p) will be taken to be 0.5, as recommended in Section A.5.1 of Appendix A to NUREG-1757. The factor of 100 corrects for probe areas that are not 100 cm^2. In the case of a scan measurement, the counting interval is the time the probe is actually over the source of radioactivity. This time depends on scan speed, the size of the source, and the fraction of the detector's sensitive area that passes over the source; with the latter depending on the direction of probe travel. The source efficiency term (ε_s) in Equation 5-20 may be adjusted to account for effects such as self-absorption, as appropriate.

An example calculation to determine the $MDC_{structure, scan}$ for the detection of Co-60 with a 100 cm^2 gas proportional detector follows.

Assumptions:

Probe width = 4 inches
Scan rate = 2 inches/sec
Background count rate = 200 cpm
t = 2 seconds = 0.033 minute
B = 6.7 counts in the measurement time interval (t)
p = 0.5
ε_i = 0.38 counts per emission
ε_s = 0.25 (from ISO 7503-1) emissions per disintegration
A = 100 cm^2

$$MDC_{structure, scan} = \frac{1.38\sqrt{6.7}}{\sqrt{0.5}(0.38)(0.25)\left(\frac{100}{100}\right)(0.033)} = 1611 \text{dpm}/100\text{cm}^2$$

Actual values for ε_s will be selected from ISO 7503-1 or NUREG-1507 or empirically determined and documented prior to performing the final status survey.

5.6.2.4.3 MDCs for Alpha Scan Surveys for Structure Surfaces

In cases where alpha scan surveys are required, MDCs must be quantified differently than those for beta-gamma surveys because the background count rate from a typical alpha survey instrument is nearly zero (1 to 3 counts per minute typically). Since the time that an area of alpha activity is under the probe varies and the background count rates of alpha survey instruments is so low, it is not practical to determine a fixed MDC for scanning. Instead, it is more useful to determine the probability of detecting an area of contamination at a predetermined DCGL for given scan rates. In general, it is expected that separate alpha and beta surface activity measurements will not be necessary at the YNPS and that surrogate measurements will instead be used for alpha surface activity assessments (see Section 5.4.6.2).

For alpha survey instrumentation with a background around one to three counts per minute, a single count will give a surveyor sufficient cause to stop and investigate further. Thus, the probability of detecting given levels of alpha emitting radionuclides can be calculated by use of Poisson summation statistics. Doing so (see MARRSIM Section 6.7.2.2 and Appendix J for details), one finds that the probability of detecting an area of alpha activity of 300 dpm/100cm^2 at a scan rate of 3 cm per second (roughly 1 inch per second) is 90% if the probe dimension in the direction of the scan is 10 cm. If the probe dimension in the scan direction is halved to 5 cm, the detection probability is still 70%. Choosing appropriate values for surveyor efficiency, instrument and surface efficiencies will yield MDCs for alpha surveys for structure surfaces. If for some reason lower MDCs are desired, then scan speeds can be adjusted, within practical limits, via the methods of Section 6.7.2.2 and Appendix J of the MARSSIM.

5.6.2.4.4 MDCs for Gamma Scans of Land Areas

Section A.5.1 of Appendix A to NUREG-1757, the values given in Table 6.7 of MARSSIM may be adopted for gamma scans of land areas if NaI detectors of the dimensions considered in the table are used. If larger NaI detectors (e.g., 3 inch by 3 inch) or other detector types (e.g., plastic scintillator) are used, then the scan MDC will be computed using the methods of Section 6.7.2.1 of MARSSIM. This is the same method as was used to derive the values given in MARSSIM Table 6.7. As an alternative, a specific technical study may be performed and documented to establish efficiency to a soil standard consistent with MARSSIM guidance.

The radionuclides represented in MARSSIM Table 6.7 encompass those expected to be encountered in gamma scans for land areas at the YNPS. If desired, the methods of Sections 5.4.6.1 and 5.4.6.2 of this plan may be used to establish scan MDCs based on radionuclide mix ratios. Alternatively, the most limiting value for the radionuclide mix may be used, with most limiting in this case meaning the radionuclide for which the MDC is the largest fraction of its $DCGL_W$ for soil, while still meeting the criteria of 5.5.3.1.

An example calculation to determine the $MDC_{\text{land scan}}$ for the detection of Cs-137 with a 2”x2” NaI detector is shown below.

The minimum detectable count rate (MDCR) for a surveyor must be calculated prior to determining the scan MDC. The MDCR is dependent upon the background counts expected during time, t, at which the detector is located over the localized contamination. The minimum detectable count rate (MDCR) for a surveyor is calculated using the following expression:

$$\mathrm{MDCR}_{\text{surveyor}} = \frac{1.38\sqrt{b}}{\sqrt{p}\ t} \qquad \text{(Equation 5-21)}$$

where b = the background counts expected during time, t
t = the time the detector is located above the localized contamination
p = the surveyor efficiency

Assumptions:

Scan speed = 0.5 meters/sec
Localized contamination diameter = 56 cm
Background count rate = 7000 cpm
b = 130.67 counts in the measurement time interval (t)
t = 0.0187 minute
p = 0.5

$$MDCR_{surveyor} = \frac{1.38\sqrt{130.67}}{\sqrt{0.5}\ (0.019)} = 1195\,cpm$$

Next, the minimum detectable exposure rate (MDER) is calculated by dividing the $MDCR_{surveyor}$ by the response to exposure rate factor for Cs-137 of 900 cpm/μR/h from MARSSIM Table 6.7 as follows:

$$MDER = \frac{1195cpm}{900cpm/mR/h} = 1.33mR/h$$

The Microshield™ modeling code is used to calculate the exposure rate from the localized contamination. Assuming a localized contamination depth of 15 cm, a density of 1.6 g/cm^3, a dose point of 10 cm above the surface and an initial concentration of 5 pCi/g of Cs-137, results in a calculated exposure rate equal to 1.307 μR/h. The scan MDC is calculated by dividing the MDER by the localized contamination exposure rate conversion factor as follows:

$$Cs-137scanMDC = 5pCi/g\frac{1.33mR/h}{1.307mR/h} = 5.1pCi/g$$

The scan MDCs will be documented prior to performing the final status survey.

5.6.2.5 Scan MDCs for Hot Particles

The scan MDC and scan methodologies for instruments used for structure surfaces (beta sensitive detectors) and land areas (gamma sensitive detectors) are capable of detecting very small areas of elevated radioactivity that could be present in the form of small particles (i.e. hot particles). The minimum detectable particle activity for these scanning instruments and methods correspond to a small fraction of the TEDE limit provided in 10CFR20 subpart E.

5.6.2.6 Typical Instrumentation and MDCs

Table 5-4 provides nominal data for the types of field instrumentation anticipated for use in the final survey efforts for YNPS. The efficiencies listed in Table 5-4 are the total efficiencies in counts/disintegration, and the background count-rates shown are nominal values for generic materials. This table is provided to show the relative sensitivity of some of the types of instruments that will be used during the final status surveys and allow the readers to compare the sensitivities to the DCGLs in Section 6 of the LTP. The instrument efficiency (ε_I) and source efficiency (ε_s) will be evaluated for instruments used for final status survey measurements and documented as part of the calibration records. This evaluation will include the effects of surface to detector distances, surface coatings and the depth of contamination in material (e.g., concrete) on instrument performance. Instrument calibration sources will be chosen that are appropriate for use for the radionuclides expected to be present post remediation. Instrument readings will be converted to activity by selecting conservative efficiency factors based upon the building surface conditions (including the depth of contamination in concrete).

Table 5-4
Available Instruments and Nominal Detection Sensitivities

Instrument	Application	Nominal Efficiency (Not Media Specific)	Nominal Background	Nominal MDC (fixed measurement)	Nominal Scan MDC
pancake GM probe (20 cm^2)	beta-gamma scans or fixed measurements for structure surfaces	17% (Tc-99)	50 cpm	1,050 dpm/100 cm^2 (1 minute count)	3140 dpm/100 cm^2
gas proportional counter (100 cm^2)	alpha or beta scans or fixed measurements for structure surfaces	β plateau: 16% (Tc-99); α plateau: 23% (Am-241)	350 cpm (β plateau); 15 cpm (α plateau)	560 dpm/100 cm^2 (β plateau) 90 dpm/100 cm^2 (α plateau); 1 minute counts	1770 dpm/100 cm^2 (β plateau); 400 dpm/100 cm^2 (α plateau)
plastic scintillator (100 cm^2)	beta-gamma scans or fixed measurements for structure surfaces	30% (Co-60)	600 cpm	390 dpm/100 cm^2 (1 minute count)	1230 dpm/100 cm^2
dual-phosphor scintillator (100 cm^2)	scans or fixed measurements; α and β, independently or simultaneously	20% (Co-60) 18% (Am-241)	300 cpm (β mode); 6 cpm (α mode)	420 dpm/100 cm^2 (β mode); 80 dpm/100 cm^2 (α mode)	1300 dpm/100 cm^2 (β mode); 400 dpm/100 cm^2 (α mode)
ZnS scintillator (100 cm^2)	alpha scans or fixed measurements on structure surfaces	19% (Pu-239)	2 cpm	50 dpm/100 cm^2 (1 minute count time)	400 dpm/100 cm^2
HPGe	in-situ gamma spectroscopy – soil	Varies with energy and geometry	Varies with energy and geometry	0.05 pCi/g Co-60 0.05 pCi/g Cs-137 (10 minute counts)	N/A
NaI(Tl)	Soil Gamma Scan	.12%	10,000 cpm	N/A	1.6 pCi/g Co-60* 6.3 pCi/g Cs-137
position-sensitive proportional counter	scan-and-record surveys	Co-60 (β): 18% Am-241 (α): 23%	350 cpm/100 cm^2 beta 15 cpm/100 cm^2 alpha	Typical values are 1,925 dpm/100 cm^2 β and 200 dpm/100 cm^2 α	

*Assumes a 56 cm diameter by 15 cm deep soil contamination volume.

5.6.3 Survey Considerations

The available complement of survey instrumentation and techniques will be evaluated to select an integrated approach that will effectively measure residual radioactivity for a given survey unit. The survey design must rely on both the historical site assessment and pertinent data from characterization or remediation support surveys to ensure a complete survey approach. Considerations that will be addressed in the selection of survey instrumentation and techniques include, but are not limited to:

- the types of measurements required;
- suitability for the expected physical and environmental conditions;
- MDCs for advanced survey methods, traditional scanning surveys, fixed measurements, and sampling relative to the $DCGL_W$ and the $DCGL_{EMC}$;
- radionuclide mix, including difficult-to-detect and alpha-emitting radionuclides;
- expected spatial variability of any suspected residual contamination;
- accessibility of areas (may impact coverage for scanning surveys); and
- the need for any judgmental assessments to address areas believed to have a higher potential for contamination or situations such as potential sub-surface contamination where prudence would dictate some additional sampling.

5.6.3.1 Survey Considerations for Buildings and Structures

The condition of surfaces following decontamination activities can affect the choice of survey instruments and techniques. Removing contamination that has penetrated a surface usually involves removing the surface material. As a result, the floors and walls of decontaminated facilities can be scarred or broken up and uneven. Such surfaces are more difficult to survey because it is not possible to maintain a fixed distance between the detector and the surface. In addition, scabbled or porous surfaces may attenuate radiation - particularly alpha and low-energy beta particles, and pose an increased risk of damage to detector probe faces. Surface irregularities may also cause difficulty in rolling or maneuvering detector systems on wheels.

Part of the planning for the final status survey of a particular survey unit will include an evaluation of the surfaces to be monitored. For conventional instrumentation, surface anomalies will be identified as part of this process and will be taken into account when selecting efficiencies to convert instrument readings to activity and in the calculation of the corresponding MDCs. Conservative values will be chosen based upon surface conditions. If the condition of the surface in the area changes in a more conservative direction (e.g. shorter detector to surface distance), the effect on the MDC will be assessed but may not be re-derived. If the condition of the surface changes in a non-conservative direction (e.g. different construction material which has higher natural radioactivity) the MDC will be assessed and re-derived.

Expansion joints, stress cracks, floor/wall interfaces, and penetrations into floors and walls for piping, conduit, anchor bolts, etc., are potential sites for accumulation of contamination and pathways for migration into sub-floor soil and hollow wall spaces. Roof surfaces and drainage points are also important survey locations. In some cases, it may be necessary to core, drill, or use other methods as necessary to gain access to areas for sampling.

5.6.3.1.1 Activity Beneath Surfaces

Floors and walls of structures may have surface irregularities such as cracks and crevices that require special consideration in the survey process. Such considerations may consist of fixed measurements, longer count times, adjustments to counting efficiencies, sampling of material, or any combinations of these approaches.

Plant areas where residual radioactive material beneath a painted surface is known or suspected to be present will also require special consideration. Sampling will be performed, as appropriate, to confirm or deny the presence of residual activity. If activity is found, the samples should be used to determine both the radionuclides that are present and the density-thickness of the paint layer(s) in order to assess the need for correction factors for counting efficiencies. Such corrections, if required, will be determined following the guidance given in Section 5 of NUREG-1507. The effect of any such corrections on instrument MDCs will be assessed to ensure that measurements can still be performed with the required sensitivity relative to the applicable DCGLs.

5.6.3.1.2 Exterior Surfaces of Building Foundations

Exterior surfaces of below-grade foundations will be evaluated using the historical site assessment and other pertinent records to determine the potential for sub-surface contamination on the exterior surfaces of below-grade foundations. One method available to evaluate the exterior surfaces is the use of core bores through foundation or walls and the taking of soil samples at locations having a high potential for the accumulation and migration of radioactive contamination to sub-surface soils. These biased locations for soil and concrete assessment could include stress cracks, floor and wall interfaces, penetrations through walls and floors for piping, run-off from exterior walls, and leaks or spills in adjacent outside areas, etc. If the soil is found to be free of residual radioactivity at the biased locations, it will be assumed that the exterior surface of the foundation is also free of residual activity. Otherwise, additional sampling may be necessary to determine the extent of decontamination and remediation efforts. Another method available for evaluating the exterior surfaces of below-grade foundations is gamma well logging. Soil in biased locations next to the exterior of the buildings may be evaluated using this technique. This technique can provide for rapid isotopic analysis of soils without sampling.

5.6.3.1.3 Buried Piping, Storm Drains, Sewer Systems, Plumbing and Floor Drains

Buried piping, storm drains, plumbing and floor drains are being removed or free-released in accordance with existing plant procedures.

Non-RCA sanitary systems at the YNPS Plant drain to on-site leach fields. These systems are independent of other plant systems and surface water or storm drains. If any residual radioactivity is suspected in portions of the sanitary plumbing systems, evaluations for both the leach fields and the associated system piping may be required. Evaluations required for any affected leach fields will be made as described in Section 5.6.3.2.2 of this plan, for sub-surface activity.

5.6.3.2 Survey Considerations for Outdoor Areas

5.6.3.2.1 Residual Radioactivity in Surface Soils

In this context, surface soil refers to outdoor areas where the soil is considered to be uniformly contaminated from the surface down to 15 centimeters. These areas will be surveyed through combinations of sampling, scanning, and in-situ measurements, as appropriate.

5.6.3.2.2 Residual Radioactivity in Subsurface Soils

Residual radioactivity in subsurface soils refers to residual radioactivity residing under the top 15 centimeters of soil or underneath structures such as building floors/foundations. Such areas include, but are not limited to, areas under buildings, building floors/foundations, or components where leakage was known or suspected to have occurred in the past and on-site storage areas where radioactive materials have been identified. However, the assessment of subsurface soil contamination is not currently complete. Soil in difficult to access areas such as under buildings will be deferred until later in the decommissioning process. As a part of survey planning, borehole logs will be reviewed, when available.

The DQO process for subsurface areas will be similar to the DQO process used for other surveys at YNPS (e.g., final status survey for surface soils). However, there may be differences in design input parameters as necessary to satisfy the objectives of the plan. Additional detail regarding subsurface input parameters and methodology are provided below. Surveys (i.e., characterization, remediation and final status survey) for subsurface areas will be performed under a documented survey plan developed using the DQO process. The level of effort with which the DQO process is used as a planning tool is commensurate with the type of survey and the necessity of avoiding a decision error. This is the graded approach of defining data quality requirements as described previously in the LTP. For example, characterization survey plans intended to collect data might only require a survey objective and the instrumentation and analyses specifications necessary to meet that survey objective. Remediation and final status plans which require decisions would need additional effort during the planning phase according to the level of risk of making a decision error and the potential consequences of making that error.

Evaluation of subsurface soil at YNPS during final status survey will be a combination of systematic and biased measurements. Measurements may be either in-situ gamma spectroscopy by well logging or other advanced technology, provided the MDC meets the criteria discussed in Section 5.6.2.5, or by sampling. If advanced technology instrumentation is selected for use, a technical support document will be developed which describes the technology to be used and how the technology meets the objectives of the survey. This document will be available for NRC inspection in support of final status survey activities. Sample locations will use a random start, systematic grid, supplemented with biased measurements. Biased measurements will be obtained at the locations of localized contamination. Where samples are taken, each 3-meter core will be homogenized and measured.

The horizontal extent of contamination will be investigated by judgmental sampling in areas that exceed the $DCGL_w$ and for samples within a systematic sampling area that exceed the $DCGL_{EMC}$. For the case where the $DCGL_{EMC}$ comparison is made, the value used for the area factor will be determined from the area bounded by the adjacent samples or by the area bounded by the locations that exceed the $DCGL_W$. Thus, for samples that exceed the $DCGL_{EMC}$, the investigation criteria will be the $DCGL_W$. This approach is consistent with the model used to calculate DCGLs in Section 6.

As discussed in Section 2.6, a portion of the YNPS industrial area has been identified as requiring additional investigation of subsurface soils. Twenty-five (25) measurement locations will be sampled in this area (see Figure 2-6 for the area of additional subsurface investigation). Biased measurements or samples will be obtained in these areas based upon characterization data and professional judgment. If a calculated sample location falls on a building foundation, a sample will be obtained at that location unless the building is in contact with bedrock. All samples will be evaluated against the soil DCGLs by using either the Sign or WRS test.

Investigation levels applicable to surface soils (given in Table 5-2) will be applied to subsurface soils. Similarly the area factors for surface soils will be applied to subsurface soils. That is, no sample can exceed the $DCGL_{EMC}$ without an investigation being performed. These investigations would be similar to those performed for surface soils.

Samples will be obtained to a depth of 3 meters or bedrock, whichever is reached first. These samples will be homogenized over the entire depth of the core obtained. In cases where refusal is met because of bedrock, the sample will be used "as is." In cases where a non-bedrock refusal is met prior to the 3-meter depth, the available sample will be used to represent the 3-meter sample, if the viable sample is at least 1.5 meters in depth. If a non-bedrock refusal is met before the 1.5-meter depth, then a new sample will be obtained within a 3-meter radius from the original location. Samples will be analyzed by gamma spectrometry. A minimum of 5% of the samples will be analyzed for hard-to-detect radionuclides. During specific investigations, analysis of a larger percentage of samples for hard-to-detect radionuclides will be performed.

5.6.3.2.3 Paved areas

Paved areas that remain at the YNPS following decommissioning activities may require surveys for residual radioactivity on the surface, beneath the surface, or both. As part of the survey design and planning process, historical information will be reviewed to determine whether radiological incidents or plant alterations have occurred in the survey unit. Where indications are that impacted soil could have been mixed by grade work prior to paving, this will be factored into final survey design to establish a reasonable depth of disturbed soil for evaluation. If it is determined that the soil beneath pavement has been impacted, the final status survey will incorporate appropriate surveys and sampling.

If residual radioactivity is primarily on or near the surface of the paved area, for purposes of surveying, measurements will be taken as if the area were surface soil. If the residual radioactivity is primarily beneath the paving, it will be treated, for purposes of surveying, as subsurface residual radioactivity.

5.6.3.2.4 Groundwater

Assessments of any residual activity in groundwater at the YNPS will be via groundwater monitoring wells. The monitoring wells installed at the site will monitor groundwater at both deep and shallow depths. Section 2.7 describes the groundwater monitoring to be conducted.

The data collected from the monitoring wells, across multiple aquifers, will be used to ensure that the concentration of well water available, based upon the well supply requirements assumed in Section 6 for the resident farmer, is below the EPA MCLs. This will ensure that the dose contribution from groundwater is a small fraction of the limit in 10CFR20.1402.

5.6.3.2.5 Sediments

Sediments will be assessed by collecting samples within locations of surface water ingress or by collecting composite samples of bottom sediments, as appropriate. Such samples will be collected using approved procedures based on accepted methods for sampling of this nature. Sample locations will be established using the methods of Section 5.5.1 of this plan. Scanning in such areas is not applicable.

Sediment samples will be evaluated against the DCGLs for soil. This is considered appropriate given that the action that would result in the greatest radiological impact to future inhabitants of the site would be to dredge up the sediment and use it for farming. If the sediment is left in place, then use of the soil DCGLs is conservative since many of the pathways considered in developing the soil DCGLs (direct exposure, uptake by plants, etc.) would not apply.

Assessment of residual activity levels in surface water drainage systems will be via sampling of sediments, fixed measurements, or both, as appropriate, making measurements at traps and other appropriate access points where activity levels should be representative or bound those on the interior surfaces.

5.7 Final Status Survey Data Assessment

The Data Quality Assessment (DQA) process is an evaluation method used during the assessment phase of FSS to ensure the validity of FSS results and demonstrate achievement of the survey plan objectives. The level of effort expended during the DQA process will typically be consistent with the graded approach used during the DQO process. The DQA process will include a review of the DQOs and survey plan design, will include a review of preliminary data, will use appropriate statistical testing when applicable (statistical testing is not always required, e.g., when all sample or measurement results are less than the $DCGL_W$), will verify the assumptions of the statistical tests, and will draw conclusions from the data. Application of DQAs will be described in greater detail in the YNPS Final Status Survey (FSS) Quality Assurance Project Plan.

Prior to evaluating the data collected from a survey unit against the release criterion, the data are first confirmed to have been acquired in accordance with applicable procedures and QA/QC requirements. Any discrepancies between the data quality or the data collection process and the applicable requirements are resolved and documented prior to proceeding with data analysis. Data assessment will be performed, by trained personnel, using approved site procedures.

The first step in the data assessment process is to convert the survey results to DCGL units. Next, the individual measurements and sample concentrations will be compared to DCGL levels for evidence of small areas of elevated activity or results that are statistical outliers relative to the rest of the measurements (see Section 5.5.3.1). Graphical analyses of survey data that depict the spatial correlation of the measurements are especially useful for such assessments and will be used to the extent practical. The results may indicate that additional data or additional remediation and re-survey may be necessary. If this is not the case, the survey results will then be evaluated using direct comparisons or statistical methods, as appropriate, to determine if they exceed the release criterion. If the release criterion has been exceeded or if results indicate the need for additional data points, appropriate further actions will then be determined.

Interpreting the results from a survey is most straightforward when all measurements are higher or lower than the $DCGL_W$. In such cases, the decision that a survey unit meets or exceeds the release criterion requires little in terms of data analysis. However, formal statistical tests provide a valuable tool when a survey unit's measurements are neither clearly above nor entirely below the $DCGL_W$.

The first step in evaluating the data for a given survey unit is to draw simple comparisons between the measurement results and the release criterion. The result of these comparisons will be one of three conclusions: 1) the unit meets the release criterion; 2) the unit does not meet the release criterion; or 3) no conclusion can be drawn from simple comparisons and thus one of the non-parametric statistical tests must be applied. The initial comparisons made for the results for a given survey unit depend on whether or not the results are to be compared against a background reference area.

If the survey data are in the form of gross (non-radionuclide-specific) measurements or if the radionuclide of interest is present in background in a concentration that is a relevant fraction of the $DCGL_W$, then the initial data evaluation will be as described in Table 5-5.

Table 5-5
Initial Evaluation of Survey Results
(Background Reference Area Used)

Evaluation Result	Conclusion
Difference between the maximum concentration measurement for the survey unit and the minimum reference area concentration is less than the $DCGL_W$	Survey unit meets the release criterion
Difference between the average concentration measured for the survey unit and the average reference concentration is greater than the $DCGL_W$	Survey unit does not meet the release criterion
Difference between any individual survey result and any individual reference area concentration is greater than the $DCGL_W$ and the difference between the average concentration and the average for the reference area is less than the $DCGL_W$	Conduct either the Wilcoxon Rank Sum test or the Sign test; and the EMC test

If the survey data are in the form of radionuclide-specific measurements and the radionuclide(s) of interest is not present in background in a concentration that is a relevant fraction of the $DCGL_W$, then the initial data evaluation will be as described in Table 5-6.

Table 5-6
Initial Evaluation of Survey Results
(Background Reference Area Not Used)

Evaluation Result	Conclusion
All measured concentrations less than the $DCGL_W$	Survey unit meets the release criterion
Average concentration exceeds the $DCGL_W$	Survey unit does not meet the release criterion
Individual measurement result(s) exceeds the $DCGL_W$ and the average concentration is less than the $DCGL_W$	Conduct the Sign test and the EMC test

5.7.1 Wilcoxon Rank Sum Test

Gross activity measurements or measurements for which the radionuclide of interest exists in background in concentrations that are a relevant fraction of the $DCGL_W$ may be evaluated using the Wilcoxon Rank Sum (WRS) test. In the WRS test, comparisons are made between the survey results for a given survey unit and reference (background) data for comparable materials. However, for survey units which contain multiple materials having different backgrounds, it may be advantageous to background-subtract gross activity measurements (using paired observation) and apply the Sign test (see Section 5.7.2).

The WRS test tests the null hypothesis that the median concentration in the survey unit exceeds that in the reference area by more than the $DCGL_W$. The null hypothesis is assumed to be true unless the statistical test indicates that it should be rejected. The other possibility is that the median concentration in the survey unit exceeds that in the reference area by less than the $DCGL_W$. Note that some or all of the survey unit measurements may be larger than some reference area measurements, while still meeting the release criterion. Indeed, some survey unit measurements may exceed some reference area measurements by more than the $DCGL_W$. The result of the hypothesis test determines whether or not the survey unit as a whole is deemed to meet the release criterion. The EMC is used to screen individual measurements.

The WRS test is applied as described in the following steps:

1. List the survey measurements.
2. Adjust the reference area measurements by adding the $DCGL_W$ to each one.
3. Pool the adjusted reference area measurements and the sample (survey unit) measurements and rank them in increasing order from 1 to the total number of data points (reference measurements plus sample measurements).
4. For any measurements that have the same value, the rank assigned to that set of measurements is the average of their ranks.
5. Sum the ranks of the adjusted reference area measurements.
6. Compare the sum of the adjusted reference area measurements (W_r) with the critical value from Table I.4 of the MARSSIM for the appropriate values of m (the number of

reference measurements), n (the number of sample measurements), and α (the decision error rate).

If the value W_r determined from steps 1 through 6 above exceeds the critical value from Table I.4 of the MARSSIM, then the null hypothesis is rejected and the alternate accepted. In other words, the results show that the survey unit meets the release criterion.

Note that the WRS test described in steps 1 through 6 above assumes that there are no "less than" results in the data set, i.e., that all of the data points have a quantitative value rather than "background" or "less than MDC." Though it is not anticipated that data of this nature would be among that collected for a final status survey, if it is encountered and must be used, the method described in Section 8.4.2 of the MARSSIM will be used to assign rank to these values. If more than 40% of the data collected for a final status survey are "less than" values, then the WRS test cannot be used.

5.7.2 Sign Test

Radionuclide specific measurements for which the radionuclide(s) of interest either does not exist in background or is not present in a concentration that is a relevant fraction of the $DCGL_W$ will be evaluated using the Sign test. In addition, the Sign test may be used to evaluate gross activity measurements from survey units containing multiple materials by subtracting the appropriate background using paired measurements.

The null hypothesis tested by the Sign test is the same as that used for the WRS test. As with the WRS test, some individual survey unit measurements may exceed the $DCGL_W$ even when the survey unit as a whole meets the release criterion. In fact, a survey unit average that is close to the $DCGL_W$ might have almost half of its individual measurements greater than the $DCGL_W$. Such a survey unit may still not exceed the release criterion. As with the WRS test, the EMC is used to screen individual measurements.

The Sign test is applied as described in the following steps:

1. List the survey measurements.
2. For each survey unit measurement, subtract the measurement from the $DCGL_W$ and record the differences.
3. Discard any difference that is exactly zero and reduce the total number of measurements (N) by the number of zero differences.
4. Count the number of positive differences. This value is the test statistic S+.
5. Compare the number of positive difference (S+) to the critical values from Table I.3 of MARSSIM for the appropriate values of N (total measurements) and α (decision error rate). (A positive difference corresponds to a measurement below the $DCGL_W$ and contributes evidence that the survey unit meets the release criterion.)

If S+ is greater than the critical value in Table I.3 of MARSSIM, then the null hypothesis is rejected and the alternate accepted.

Note that "measurements" in Step 1 above refers to the net result in cases where background-subtracted gross activity measurements (using the paired observation methodology) are being evaluated.

Though it is not anticipated, if any of the data collected from a final status survey are reported as "less than MDC" or as background, actual values will be assigned, even if negative, for purposes of applying the Sign test.

5.7.3 Elevated Measurement Comparison

The Elevated Measurement Comparison (EMC) consists of comparing each measurement from the survey unit with the investigation levels discussed in Section 5.5.3. The EMC is performed for both measurements obtained on the systematic-sampling grid and for locations flagged by scanning measurements. Any measurement from the survey unit that is equal to or greater than an investigation level indicates an area of relatively high concentrations that should be investigated, regardless of the outcome of the nonparametric statistical tests. Thus, the use of the EMC against the investigation levels may be viewed as assurance that unusually large measurements will receive proper attention regardless of the outcome of those tests and that any area having the potential for significant dose contributions will be identified. The EMC is intended to flag potential failures in the remediation process. It should not be used as the primary means to identify whether or not a unit meets the release criterion.

If residual radioactivity exists in an isolated area of elevated activity in addition to residual radioactivity distributed relatively uniformly across a survey unit, the unity rule will be used to ensure that the total dose is within the release criterion, i.e.,

$$\frac{\delta}{DCGL_W} + \frac{\overline{C}_{elevated} - \delta}{(AreaFactor) \times DCGL_W} < 1 \qquad \text{(Equation 5-22)}$$

where: δ = average concentration outside the elevated area,
$\overline{C}_{elevated}$ = average concentration in the elevated area.

A separate term will be used in Equation 5-22 for each elevated area identified in a survey unit.

Note that EMC considerations generally apply only to Class 1 survey units, since areas of elevated activity should not exist in Class 2 or Class 3 survey units.

5.7.4 Unity Rule

When radionuclide specific measurements are made in survey units having multiple radionuclides, compliance with the radiological release criterion will be assessed through use of the unity rule, also known as the sum of fractions. The unity rule, represented in the expression below, is satisfied when radionuclide mixtures yield a combined fractional concentration limit that is less than or equal to one, i.e.:

$$\frac{C_1}{DCGL_1} + \frac{C_2}{DCGL_2} + ... + \frac{C_n}{DCGL_n} \leq 1 \qquad \text{(Equation 5-23)}$$

where:

C_n = Concentration of radionuclide n
$DCGL_n$ = DCGL for radionuclide n

5.7.5 Data Assessment Conclusions

The result of the data assessment is the decision to reject or not to reject the null hypothesis. Provided that the results of investigations triggered by the EMC were resolved, a rejection of the null hypothesis leads to the decision that the survey unit meets the release criterion. If the data assessment concludes that the null hypothesis cannot be rejected, this may be due to one of two things: 1) the average residual concentration in the survey unit exceeds the $DCGL_W$; or 2) the analysis did not have adequate statistical power. "Power" in this context refers to the probability that the null hypothesis is rejected when it is indeed false. Quantitatively, the power is 1 - β, where β is the Type II error rate (the probability of accepting the null hypothesis when it is actually false). A retrospective power analysis can be used in the event that a survey unit is found not to meet the release criterion to determine if this is indeed due to excess residual activity or if it is due to an inadequate sample size.

Retrospective power analyses, if necessary, will be performed following the methods of MARSSIM Sections I.9 and I.10 for the Sign test and WRS test, respectively. If the retrospective power analysis indicates insufficient power, then an assessment will be performed to determine whether the observed median concentration and/or observed standard deviation are significantly different from the estimated values used during the DQO process. The assessment may identify and propose alternative actions to meet the objectives of the DQOs. These alternative actions may include failing the unit and starting the DQO process over, remediating some or all of the survey unit and starting the DQO process over and adjusting the LBGR to increase sample size. For example, the assessment determines that the median residual concentration in the survey unit exceeds the $DCGL_W$ or is higher than was estimated and planned for during the DQO process. A likely cause of action might be to fail the unit or remediate and resurvey using a new sample design. As another example, the assessment determines that additional samples are necessary to provide sufficient power. One course of action might be to determine the number of additional samples and collect them at random locations. Note, this method may increase the Type I error, therefore agreement with the regulator will be necessary prior to implementation. Another action would be to resample the survey unit with a new (and appropriate) number of samples and/or a new survey design.

There may be cases where the team chooses to accept a lower power as a part of the planning process.. For instance, during the DQO process the calculated relative shift was found to be less than 1. The planning team would adjust the LBGR, evaluates the impact on power and accepts the lower power. In this case, the DQA process would require the planning team to compare the prospective power analysis with the retrospective power analysis and determine whether the lower power is still justified and the DQOs satisfied.

5.8 Final Status Survey Reports

Consistent with Section 4.5.2 of NUREG-1757, the documentation describing the final status survey for a given survey unit will include:

- An overview of the results of the final status survey;
- A discussion of any changes that were made in the final status survey from that described in the LTP;
- A description of the method by which the number of samples was determined for each survey unit;
- A summary of the values used to determine the numbers of sample and a justification for these values;
- The survey results for each survey unit including:
  - The number of samples taken for the survey unit;
  - A map or drawing of the survey unit showing the reference system and random start systematic sample locations for Class 1 and 2 survey units, and random locations shown for Class 3 survey units and reference areas;
  - The measured sample concentrations;
  - The statistical evaluation of the measured concentrations, when applicable;
  - Judgmental and miscellaneous sample data sets reported separately from those samples collected for performing the statistical evaluation;
  - A discussion of anomalous data including any areas of elevated direct radiation detected during scanning that exceeded the investigation level or measurement locations in excess of $DCGL_w$;
  - Discussion of ALARA evaluations performed and conclusions from those evaluations.
  - A statement that a given survey unit satisfied the $DCGL_w$ and the elevated measurement comparison if any sample points exceeded the $DCGL_w$;
- A description of any changes in initial survey unit assumptions relative to the extent of residual radioactivity;

- If a survey unit fails, a description of the investigation conducted to ascertain the reason for the failure and a discussion of the impact that the failure has on the conclusion that the facility is ready for final radiological surveys; and

- If a survey unit fails, a discussion of the impact that the reason for the failure has on other survey unit information.

In most cases, final status survey results will be made available to the NRC for survey areas rather than for individual survey units. Where appropriate, FSS reports may address multiple survey areas. This approach should minimize the incorporation of redundant historical assessment information and provide for a logical approach to review and independent verification in that a more complete description of the final radiological status of an area will be provided.

5.9 Final Status Survey Quality Assurance and Quality Control Measures

5.9.1 Introduction

YAEC has developed and is implementing a comprehensive Quality Assurance Program to ensure conformance with the established regulatory requirements of the Nuclear Regulatory Commission (NRC) and accepted industry standards. The participants in the Yankee Decommissioning Quality Assurance Program (YDQAP) ensure that the design, procurement, construction, testing, operation, maintenance, repair, and modifications are performed in a safe and effective manner.

The YDQAP satisfies the criteria set forth in Appendix B of 10CFR50 and is approved by the NRC as sufficient to meet the requirements of 10CFR50, 10CFR71, and 10CFR72 for QA Programs. References to specific industry standards for quality assurance and quality control measures governing final status survey activities will be reflected in supporting procedures, plans and instructions.

The quality assurance (QA) and quality control (QC) measures of the YDQAP have been integrated into the decommissioning activities, including the development of the LTP and eventual implementation of the Final Status Survey (FSS). FSS activities essential to data quality will be implemented and performed under approved procedures. Effective implementation of administrative controls will be verified through surveillance and audit activities. Corrective action will be prescribed, implemented and verified in the event any deficiencies are identified. These measures apply to the related services provided by off-site vendors, in addition to any on-site vendors and contractors or sub-contractors.

With respect to the FSS, QA/QC activities will serve to ensure that trained individuals perform the surveys. These surveys be performed using approved written procedures and properly calibrated instruments that are sensitive to the suspected contaminant. In addition, QC measures will be taken to obtain quantitative information to demonstrate that measurement results have the required precision and are sufficiently free of errors to accurately represent the site being investigated. QC checks will be performed as prescribed by the implementing procedures for both field measurements and laboratory analysis (both on-site and third party). The YAEC Nuclear Safety organization will assess the performance of FSS activities.

5.9.2 Organization

The organization described herein is defined in the YDQAP. The Chief Executive Officer (CEO) reports to the YAEC Board of Directors. The CEO is the final management authority responsible for assuring that the YDQAP is effectively implemented by the YAEC organization. The President reports to the CEO and has the necessary authority and assigned responsibility for developing, maintaining, and implementing the YDQAP. The President has delegated this responsibility to the Vice President. The Site Manager reports to the Vice-President and is responsible for implementing the YDQAP during decommissioning of the facility. The Nuclear Safety Manager reports to the Vice President and is responsible for the Quality Assurance function, which will provide independent audits and surveillances for the Final Status Survey (FSS). An organizational chart of the FSS is provided in Figure 5-1

5.9.3 Program Controls

Program Controls shall be established for performing specific FSS activities. Activities will be accomplished utilizing suitable instructions, procedures and drawings that incorporate appropriate regulatory and industry guidance.

Personnel conducting activities shall be appropriately trained and qualified. Training, qualification, and any appropriate maintenance of proficiency requirements shall be defined in administrative procedures or instructions. Professional resumes, other verifiable credentials, and/or discrete certification packages, as applicable, shall be utilized to document personnel qualifications.

5.9.4 Design Controls

Design control requirements are established to ensure that the applicable regulatory bases, codes, technical standards, and quality standards are identified in the FSS. Design controls also include independent verification and design interface control. These design controls will be implemented to determine the DCGLs, MDCs, area factors, and other DQO and FSS elements.

5.9.5 Procurement Document Control

Procurement documents related to the FSS shall be prepared in accordance with approved procedures and instructions. These procedures and instructions shall contain provisions to assure that procurement documents include or reference applicable regulatory requirements and any other requirement necessary to assure adequate quality for the purchased service, equipment, or material.

5.9.6 Instructions, Procedures, and Drawings

The performance of the FSS will require procedures for personnel training, survey implementation, data collection, chain of custody, instrument calibration and maintenance, verification, and record storage. These procedures will ensure compliance with the License Termination Plan and will meet applicable quality requirements. These include the development and approval in accordance with the site controls.

5.9.7 Document Control

Instructions, Procedures and Drawings shall be controlled as described in approved procedures or instructions. Controlled copies shall be available for use by personnel performing activities affecting the FSS Program. These controls shall assure that only current information is issued and used. The results of the FSS will be retained at least for the duration of the possession only license.

5.9.8 Control of Purchased Material, Items, and Services

Vendors may be used for the performance of the FSS and laboratory activities. Quality related services, such as instrument calibration and laboratory analysis, are procured from qualified vendors whose internal QA program is subject to approval in accordance with the YAEC Quality Assurance Program. Additionally, audits and surveillances of these contractors will be performed to provide an adequate level of assurance that the quality activities are being effectively performed and conform to the requirements of the procurement document.

5.9.9 Control of Special Processes

Procedures will be developed to implement any special processes that may be utilized in support of FSS implementation. The special processes utilized will be validated and will be implemented by trained, qualified individuals using approved procedures.

5.9.10 Inspections

Inspections and verification activities will be delineated in implementing procedures. These programs and procedures will be used to verify that sampling and surveying protocols are appropriately performed. Appropriate members of the line organization that are qualified, or an independent organization, as described in administrative procedures may perform these inspections.

5.9.11 Control of Measuring and Test Equipment

Approved procedures will be developed for the control, use, calibration, and testing of the equipment utilized for the FSS, including both laboratory and field use equipment. These procedures will ensure confidence in the data obtained. Instrument calibrations will be performed periodically in accordance with appropriate industry standards.

5.9.12 Handling, Storage and Shipping

Some of the material samples will be transported to off-site laboratories for analysis. The process for controlling this material will be sufficient to ensure that a chain-of-custody is maintained. Measures shall be established to ensure that samples are received, handled, stored, packaged, and shipped in accordance with approved procedures or instructions. These procedures or instructions shall be responsive to applicable industry or manufacturer's requirements and include controls for "shelf life" of sensitive products. Additionally, protocols must be established to ensure that there is no cross-contamination between samples and sample packaging. Appropriate controls will be defined in administrative procedures to ensure that sample integrity is maintained.

5.9.13 Control of Nonconformances

During the performance of the FSS, non-conforming conditions may be identified with equipment or services. The data associated with the non-conforming condition will be controlled until such time that it is accepted, rejected, or reworked in accordance with an appropriate procedure. Non-conforming equipment will not be utilized until conformance with applicable requirements has been established.

5.9.14 Corrective Action Program

The existing Corrective Action Program established under the YDQAP will be utilized for the FSS Program to ensure conditions adverse to quality are promptly identified and corrected.

5.9.15 Records

Measures have been established that ensure that FSS records are maintained as quality records. These measures also include procedures by which the records are reviewed and approved and procedures which ensure the records can be retrieved within a reasonable period of time. The controls shall also provide for the protection of the records to ensure that they are not lost or subject to degradation over time.

5.9.16 Audits

Audits of FSS activities will be performed periodically, in accordance with approved procedures or instructions, to verify the implementation of quality activities.

5.10 References

5-1 Title 10 to the Code of Federal Regulations, Part 20.1402, "Radiological criteria for unrestricted use."

5-2 NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual," Revision 1, dated August 2000.

5-3 Regulatory Guide 1.179, "Standard Format and Content of License Termination Plans for Power Reactors," dated January 1999.

5-4 NUREG-1727, "NMSS Decommissioning Standard Review Plan," dated September 2000.

5-5 NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance," dated September 2003.

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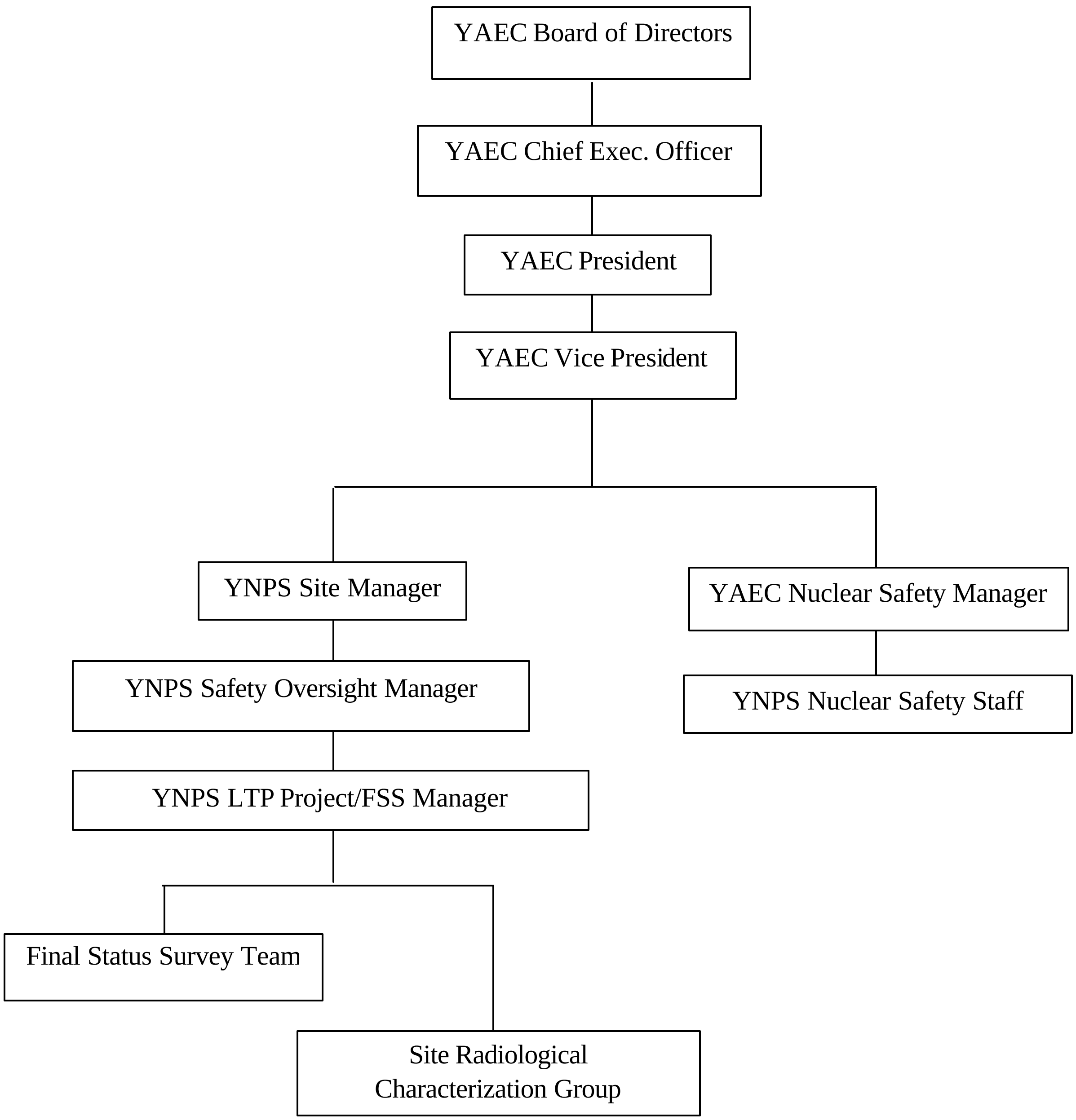
Figure 5-1
Final Status Survey Organization



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