14.0 FACILITY RADIATION SURVEYS

This section of the DP describes the results of various radiological scoping and characterization surveys that have been performed at the site and that provide the basis for the radiological designations and demarcations presented in this DP. In addition, it identifies the applicable and proposed radiological release criteria to be used for radiological surveys performed during decommissioning activities and describes the design of the final status radiological survey.

14.1 RELEASE CRITERIA

Radiological release criteria for the Tobico Marsh SGA site are of two types because they apply in distinctly different circumstances.

14.1.1 Materials and Equipment Release Criterion

The first type of release criterion is applicable to the radiological release of materials and equipment that will not be features of the site in its final condition at the time of request for license termination. This release criterion derives from published NRC regulatory policy and guidance directives that establish concentration-based decontamination limits used to decide whether an item, material, or equipment can be released from radiological controls (NRC 1987). The concentration-based decontamination limits are set near the limits of detection for standard, portable, radiation detection equipment. These limits are applied to the surfaces of structures, equipment, and components being removed from the site as part of the proposed decommissioning process. This release criterion is specified and approved in MDNR's radioactive materials license (NRC 1999a). The applicable limits for the radionuclides present at the Tobico Marsh SGA site are presented in Table 14–1.

Table 14–1 Materials and Equipment Surfaces Decontamination Limits (dpm/100cm^2)

Radiation Type	Removable	Total, Average	Total, Maximum
Alpha or Beta	200	1,000	3,000
Surface decontamination limits excerpted from USNRC, PGD 83-23 (NRC 1987)			

14.1.2 Final Status Site Release Criterion

The second type of release criterion is based upon the decommissioning dose limit for unrestricted use of the site following license termination (NRC 1997a). Unlike the first type of release criterion, the final status site release criterion is applicable to radiologically impacted structures, components, and soils that are to be left in place as a feature of the final condition of the site at the time of request for license termination.

These criteria are media-specific and derived from potential future dose to a receptor that might be exposed at the site following release.

The projected final site condition at the completion of the decommissioning activities is essentially as it currently is. MDNR has proposed the "no action" alternative as the most appropriate decommissioning alternative (see Section 6.0).[1] Since MDNR is seeking license termination without restriction on the future use of the site, the media-specific release criteria have been derived to satisfy the 25 mrem/y decommissioning dose limit as specified in 10 CFR 20.1402 (NRC 1997a).

Two potentially impacted media present in the final condition of the site have been identified. The first and most significant is the deposit of thorium-bearing slag enclosed within the disposal cell. This has been termed the "subsurface-soil source term." The second is the thin surface-soil veneer of the engineered clay cover. It has been hypothesized that this thin surface-soil veneer might have been radiologically impacted by radioactivity originating in the subsurface-soil source term and brought to the surface during previously performed subsurface-soil characterization work at the site. This has been termed the "surface-soil source term."

The radiological characteristics of the thorium-bearing slag found at the site and the dose modeling used to derive the final status site release criteria for both the surface and subsurface soil source terms are described in Sections 4.0 and 5.0 of this DP. Rather than derive DCGLs for each radionuclide separately, MDNR has derived the $DCGL_W$ for each media of concern using a composite suite of radionuclides in proportions that are known, based on characterization data, to be conservative for the source term present. The proposed soil $DCGL_W$ is then related to a single, significant radionuclide that serves as the surrogate for the mixture of radionuclides actually present in the source term. For this site, the $DCGL_W$ is associated with Th-232.

As described in Section 5.10, the subsurface-soil source term is projected to produce a peak mean annual dose well below the 25 mrem/y annual public dose limits identified by the NRC (10 CFR 20.1402) in each of the scenarios considered even when the residual radioactivity concentration is set at the specific activity limit for Th-232. Therefore, it can be deduced without further radiological survey or sampling that the subsurface-soil source term cannot possibly produce exposures that result in exceedances of the applicable dose limit, and a DCGL for the subsurface-soil source term is not necessary.

The surface-soil source term, if it is present, could potentially result in exceedances of the applicable dose limit. The Composite Recreational User scenario proves to be most limiting among the scenarios considered. The proposed media-specific $DCGL_{Ws}$ are presented in Table 14–2.

1 Planned decommissioning activities call for the demolition and removal of the LCTS building and a small concrete slab poured on the surface of the cover, and for above-grade LCTS piping to be cut and capped. These decommissioning activities are designed to remove the "attractive nuisance" presented by the structure and readily accessible LCTS piping (see Section 8.0).

Table 14–2 Media-Specific $DCGL_{Ws}$ (pCi/g)

Media	Radionuclide	$DCGL_W$
Surface Soil	Th-232	357
Subsurface Soil	Th-232	(1)

The only media at the site that are known (or assumed) to be impacted with licensed radioactivity are the subsurface-soils (the deposits of thorium-bearing slag contained by the disposal cell) and the surface-soils over the engineered clay cover. The surface soil $DCGL_W$ is derived using dose modeling presented in Section 5.0 of this DP.

(1) RESRAD dose modeling indicates that even if Th-232 concentrations were at the specific activity limit, the potential future dose to a receptor would likely be less than 1 mrem/y.

14.1.3 Elevated Measurement Comparison ($DCGL_{EMC}$) Criteria

Elevated measurement comparison concentrations ($DCGL_{EMC}$) are established to provide a sentinel or threshold concentration above which there is some potential for a locally significant amount of residual radioactivity to be present and requiring further investigation. Individual measurements from the survey unit are compared with the $DCGL_{EMC}$, and measurement values exceeding it are flagged for further investigation. The need for and use of a $DCGL_{EMC}$ is linked with the classification of the area under investigation.

The Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM, NRC 2000b) categorizes areas as either *impacted* or *non-impacted*, based upon their potential to have residual radioactivity present. Areas that have no reasonable potential for residual contamination are classified as *non-impacted areas* and final status radiological surveys are not performed in these areas. Impacted areas are further classified as *Class 1, 2,* or *3*, according to their potential for residual radioactivity to exceed the $DCGL_W$, with *Class 1* areas having the highest likelihood of exceeding the $DCGL_W$. Logically, as the potential for higher concentrations of radioactivity in an area increases, so does the potential for the presence of a locally significant amount of residual radioactivity greater than the $DCGL_W$.

Given that the potential future dose arising from radioactivity in the subsurface soil is physically limited by the specific activity of Th-232, it is evident that the actual radioactivity concentration in subsurface soil could not exceed the associated $DCGL_W$. Therefore, a $DCGL_{EMC}$ criterion is not necessary for the subsurface soil source term.

MDNR has determined that the surface soil source term meets the criteria for classification as a *Class 3* potentially impacted area. This classification, according to MARSSIM, is used for "…areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the $DCGL_W$, based on site operating history and previous radiation surveys" (NRC

2000b). As described in Section 4.3 of this DP, the operational history, routine gamma-radiation surveys performed each month since the subsurface characterization work, and a recently performed scoping survey in which scans were performed on the ground surface around former coreholes all support the classification of the surface soil source term as a *Class 3* area. While not explicitly required to be submitted for a *Class 3* area, MDNR proposes that the $DCGL_{EMC}$ be established at the $DCGL_W$ (Table 14–3). This selection is based in logic rather than dose consequence in that, for a *Class 3* area, there is essentially no expectation that concentrations of residual radioactivity will exceed the $DCGL_W$.

Table 14–3 Media-Specific $DCGL_{EMCs}$ (pCi/g)

Media	Radionuclide	$DCGL_{EMC}$
Surface Soil	Th-232	357

14.2 CHARACTERIZATION SURVEYS

The subsurface soil source term at the site has been extensively measured and characterized. Those surveys and their findings are documented in a number of reports, as they were performed over several years and by different entities.

- MDNR Survey Report (MDPH 1983)
- ORAU Radiological Assessment Survey (ORAU 1985))
- Radiological Scoping Survey (HLA 1998b)
- Characterization Survey (Cabrera 2001)

Radiological surveys performed subsequent to MDNR's acquisition of the property in 1971, along with both aerial and ground level photographs of the site taken in 1983 prior to installation of the clay cover and slurry wall, indicate that slag was evidently placed in piles on top of the previously placed sand layer and along the former access road through the center of the site. It is logical that the slag is deposited near and along the former access road, since vehicles venturing very far to the east or west of the road would have readily sunk into the saturated wetlands soil. Radiological surveys that have been performed at the site over the years yield valuable data that provide both qualitative and quantitative verification of the location of elevated concentrations of subsurface residual radioactivity. These radiological surveys corroborate the historical, photographic, and physical evidence that the slag deposits are located along the trace of the former access road through the site.

The Radiological Scoping Survey (HLA 1998b) and the subsurface soil Characterization Survey (Cabrera 2001) were both performed after placement of the clay cover and slurry walls. Both of these surveys support the conclusion that surface and near-surface soils at the site are not contaminated with residual radioactivity. They further confirm that concentrations of radioactivity in soil (both surface and subsurface) outside the footprint of the slurry walls are consistent with concentrations expected for naturally occurring background in native soils.

14.2.1 MDNR Survey Report

In April 1983, after placement of the sand cover but prior to construction of the clay cap and slurry walls, the MDNR performed a survey of a portion of the site (MDPH 1983). Representatives of the USEPA and the State of Michigan Department of Public Health were present for the survey.

A survey line, down the center of the visible former access road, was established as a reference point. Exposure rates were measured at waist level (approximately 1 meter high) using a micro-R meter along the length of this survey line. The survey was repeated moving incrementally to the east and west of the centerline until background radiation levels were consistently encountered. The areal extent of deposited radioactivity was thus demarcated. An area approximately 450 feet long and 200 feet wide appears to have been surveyed. The survey area extended beyond (in most cases well beyond) the edges of the areas of elevated radiation levels. The survey also recorded 20 μR per hour exposure rate contours indicating the areal extent of residual radioactivity as measured by gamma-radiation emission.

All elevated readings were found on or within approximately 50 feet from the former access road in areas where the ground had been disturbed or exposed. Elevated readings were not found in areas where there was no evidence of disturbance. The areal location of elevated measurements from the MDNR survey in 1983 is presented in Figure 14–1.

14.2.2 ORAU Radiological Assessment Survey

Under contract to NRC Region III, ORAU conducted a survey to assess the radiological conditions of the MDNR's portion of the former Hartley & Hartley landfill (Tobico Marsh Site). ORAU actually conducted two surveys: one in July 1984 just prior to installation of the clay cap and slurry walls and another in June 1985 after their installation (ORAU 1985). The first of the two surveys is of interest in determining the location of subsurface radioactive materials.

The first survey was designed to systematically identify the areal extent of elevated concentrations of residual radioactivity. A 20-meter grid system was established over the sand cover area and extended approximately 20 meters into the marsh on either side of this area. The area was subdivided into 10-meter grids within the sand cover area. A walkover scan was conducted using NaI(Tl) gamma scintillation detectors at 1- to 2-meter intervals over accessible portions of the property and at 5- to 10- meter intervals in the marsh areas. Locations where elevated radiation levels were measured at the ground surface were noted. Gamma exposure-rate measurements were then made both at the ground surface and at 1 meter above the surface at each grid line intersection, and at locations identified as having elevated radiation levels during the walkover surface scan. All locations of elevated radiation levels identified by either the walkover scan or the grid-node gamma exposure rate measurements were along or approximately within a 10- to 15-meter wide path corresponding to the former access road.

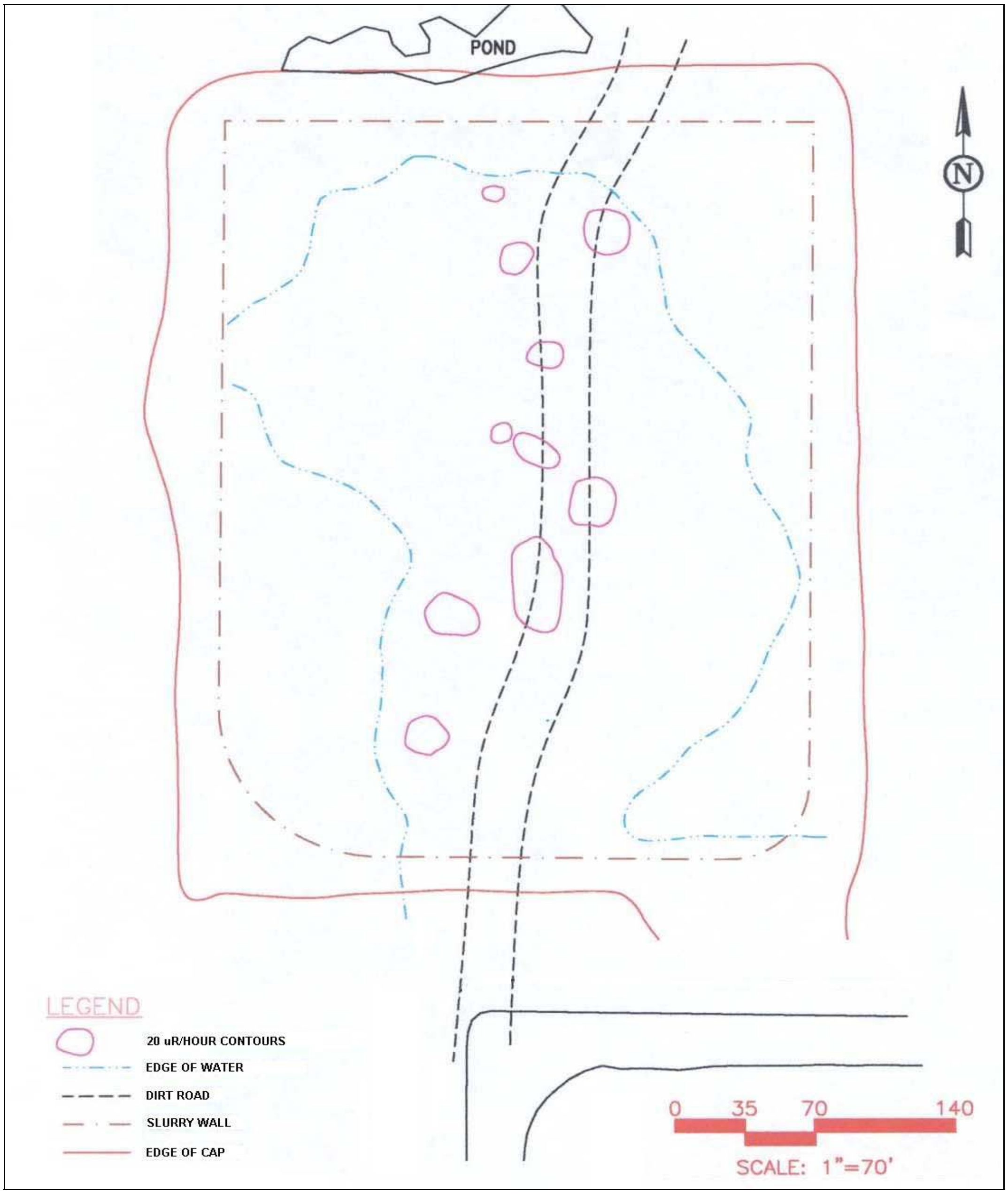

Figure 14–1 Extent of Elevated Radiation—1983 MDNR Radiological Survey

In addition to direct gamma radiation level measurements, ORAU collected surface soil samples (0- to 15-cm depth increment) at the grid nodes across the entire site and at various depths from selected locations where elevated gamma-radiation levels were measured at the ground surface.

Soil and sediment samples were analyzed by gamma spectrometry. Radionuclides of primary concern (given the analytical method and known source of the radioactivity) included Th-228 and -232, U-238, and Ra-226. Soil samples confirmed that elevated concentrations of residual radioactivity are approximately confined within this 10- to 15-meter-wide path corresponding to the former access road. The areal location of elevated measurements from the ORAU survey in 1984 (ORAU 1985) are presented in Figure 14–2.

14.2.3 Radiological Scoping Survey

A radiological scoping survey was conducted by HLA in 1998 under contract to the MDNR (HLA 1998b). The primary objectives of the scoping survey were to determine the presence of radionuclides identified in the HSA as potential constituents of concern; evaluate the relative ratios of identified radionuclides in the affected areas of the site; and determine the general levels and extent of radionuclide contamination.

The survey area consisted of the area within the slurry wall and a 20-meter-wide strip around the outside of the slurry wall.[2] A 10-meter grid system was established and mapped using a global positioning system. A walkover scan of the ground surface was again conducted using NaI(Tl) gamma scintillation detectors and covering the entire grid system (essentially 100-percent scan coverage except for grids covered by water). Sodium-iodide walkover surveys did not identify any areas with elevated gamma radiation levels.

Surface soil sampling to a depth of 1 foot was performed in the outermost grids beyond the edge of the clay cap to detect if residual radioactivity was present there. Sediment sampling was conducted in the ponded water area located to the north of the Site. GeoProbe® soil cores were obtained from 36 grids within the slurry walls and in each of the 10-meter grids surrounding the outside of the slurry walls where the installed clay cover prevented conventional surface soil sampling techniques. The core samples were screened with a gamma survey instrument to identify the segment of the core having the highest gamma radiation signal. Samples were obtained from 18 of the 36 cores collected from within the slurry walls and from 18 of the 40 cores collected from grids surrounding the slurry walls. These soil samples were analyzed in the laboratory using alpha spectroscopy, gamma spectroscopy, and gross alpha/beta analyses. Sample results confirmed that elevated Th-232 concentrations were confined to the area circumscribed by the slurry walls and that elevated radioactivity, when detected, was consistently located in the near vicinity of the former access road through the site. Measured Th-232 activity outside the slurry wall compares well with background concentrations (measurements ranged from 0.01 to 0.68 pCi/g).

2 The clay cap over the cell generally extends 5 to 10 meters beyond the slurry wall itself.

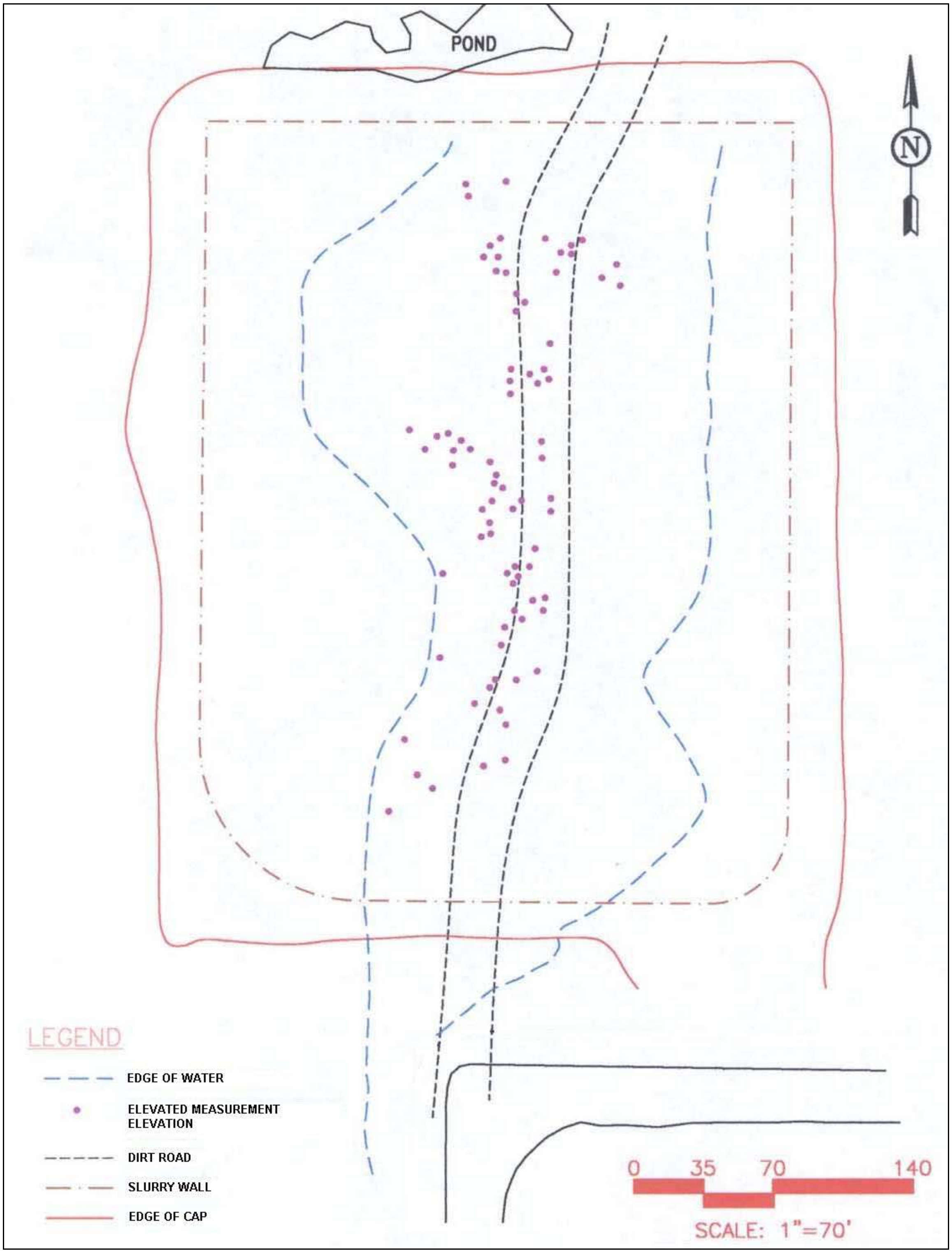

Figure 14–2 Extent of Elevated Radiation—1984 ORAU Radiological Survey

In-situ gamma spectroscopy measurements were made at the ground surface in the grids surrounding the outside of the slurry walls that were not covered by the clay cap or surface water. Downhole in-situ gamma spectroscopy measurements were made at various depths in the cased GeoProbe® holes both inside and outside of the slurry walls where the clay cover impeded a surface measurement. A total of 84 measurements were made within the 36 coreholes inside the slurry wall. A total of 49 measurements were made within 25 cased coreholes outside of the slurry wall. The casings were logged over their entire length using a NaI detector to identify depths with elevated radiation levels. In-situ gamma spectroscopy measurements made outside of the footprint of the slurry walls again indicated that Th-232 concentrations are comparable to those in non-impacted background soils, with concentrations ranging from 0.01 to 0.49 pCi/g.

The location of elevated Th-232 concentrations measured during the scoping survey was consistent with those identified in the MDNR and ORAU surveys. No sample or survey measurements identified the presence of residual radioactivity in excess of background in the area outside of the slurry walls.

14.2.4 Characterization Survey

An extensive characterization survey of the Tobico Marsh SGA Site was performed by Cabrera Services in 2000 under contract to HLA and the MDNR (Cabrera 2001). The objectives of the characterization survey were to document the three-dimensional location and concentration of residual radioactivity at the site with sufficient detail to support site-specific dose assessment, development of this decommissioning plan, and an ALARA evaluation. The survey was also aimed at generating a sufficient quantity of quality data to support a final status decision and to focus any future sampling and analysis that might be warranted in the process of terminating the MDNR's radioactive material license (NRC 1999).

The radiological characterization survey employed a number of radio-analytical techniques including: 1) downhole gross-gamma logging, 2) downhole gamma spectrometry, 3) gamma spectrometry of discrete soil samples, and 4) alpha spectrometry of discrete soil samples. Subsurface soils at the site were accessed by inserting GeoProbe® casings and core sampling tools. Watertight casings used to make in-situ measurements were advanced to a depth equal to or greater than the upper boundary of the native clay-bearing till layer underlying the site. Sample cores (physical samples) were obtained at discrete depths immediately adjacent to the GeoProbe® casing.

The extremely dense configuration of the gross-gamma logging measurements made across the site (both laterally and vertically) provides a well-defined representation of the location of buried slag bearing thorium radioactivity[3]. As previous radiological surveys concluded, residual radioactivity in soils was shown to be confined within the slurry walls and distributed principally along the former access road. The areal extent of

3 A total of 5,926 gamma logging measurements were made in 397 probe locations distributed across the site. A series of measurements were made in 1-foot increments down to or slightly into the underlying clay till.

elevated concentrations of residual radioactivity as identified by gross-gamma logging is presented in Figure 14–3.

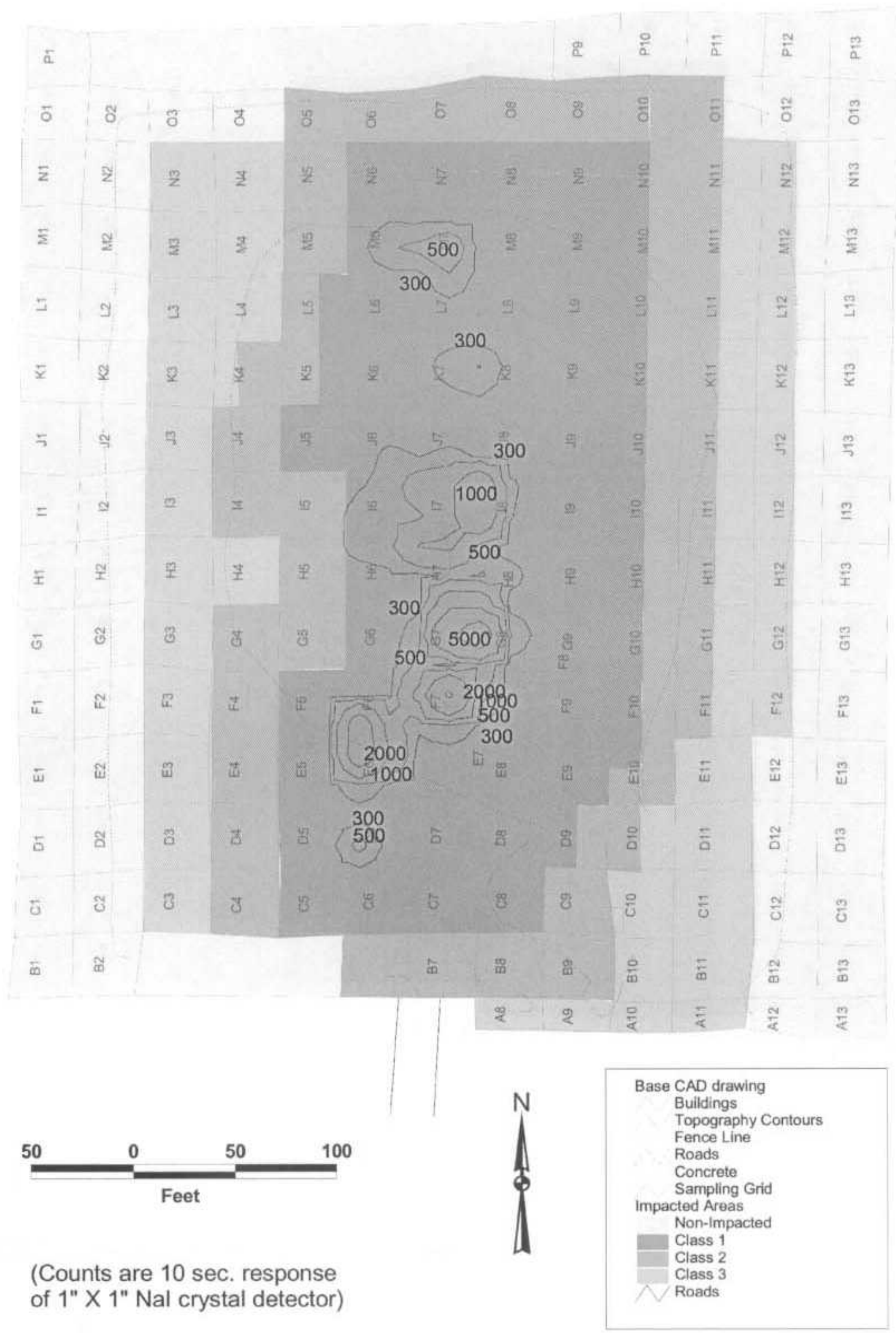

Figure 14–3 Extent of Elevated Radiation—Gamma Logging Survey

In addition to the gross-gamma logging measurements, down-hole gamma spectrometry was utilized to quantify the activity of Th-232. Again, a very dense measurement configuration was achieved.[4] Of the 2,518 gamma spectroscopy measurements performed, only 131 identified Th-232 concentrations distinguishable from background. These positive detections averaged 33 ± 106 (2σ) pCi/g of Th-232 and ranged from near background to approximately 800 pCi/g. The locations at which these positive detections occurred correlates well with the elevated measurement locations as measured by the gamma logging technique. The areal extent of elevated concentrations of residual radioactivity as identified by down-hole in-situ gamma spectroscopy measurements superimposed over the gross gamma logging extent of elevated radiation contour lines is presented in Figure 14–4.

14.2.5 Summary of the Background Radioactivity

Three different surveys have been undertaken to assess and quantify the presence of naturally occurring background radioactivity in environs surrounding the MDNR site. The first quantitative assessment of background radioactivity at the site was conducted by ORAU in conjunction with their radiological survey of the site in 1984/1985 (ORAU 1985). ORAU reported that direct gamma radiation background levels were 7 to 9 μR/h, and background concentrations in soils and sediments ranged from 0.28 to 0.96 pCi/g for Th-232 and from 0.10 to 0.89 pCi/g for Th-228. Gross-alpha background concentrations in water samples ranged from 0.21 to 8.02 pCi/L.

A second survey, focused expressly upon the detection and quantification of background concentrations of contaminants of potential concern (COPC), was completed in 1988 by ABB Environmental Services (ABB-ES) under contract to the MDNR (ABB 1998). Radiological data collected during the background study included direct gamma radiation levels, and the identification and quantification of radionuclide-specific concentrations in surface soil, subsurface soil, sediment, surface water, and groundwater. All samples were analyzed for thorium and uranium isotopes by alpha spectroscopy, for natural uranium and thorium decay-series nuclides by gamma spectroscopy (with progeny ingrowth for radium), and by gross alpha and beta counting. A summary of the results of the background assessment follows:

- 19 surface soil samples were taken. The range of Th-232 concentrations was 0.099 to 0.680 with an average of 0.252 pCi/g. The range of Th-230 concentrations was 0.094 to 0.830 with an average of 0.331 pCi/g.
- 5 subsurface soil samples were taken. The range of Th-232 concentrations was 0.151 to 0.369 with an average of 0.246 pCi/g. The range of Th-230 concentrations was 0.128 to 0.383 with an average of 0.240 pCi/g.

4 A total of 2518 in situ gamma spectrometry measurements were made in 397 casing locations distributed across the site. Spectral measurements were typically obtained at six locations (depths) within the casing. Depth selection was often biased to coincide with the depth at which the highest gross gamma logging measurements were observed.

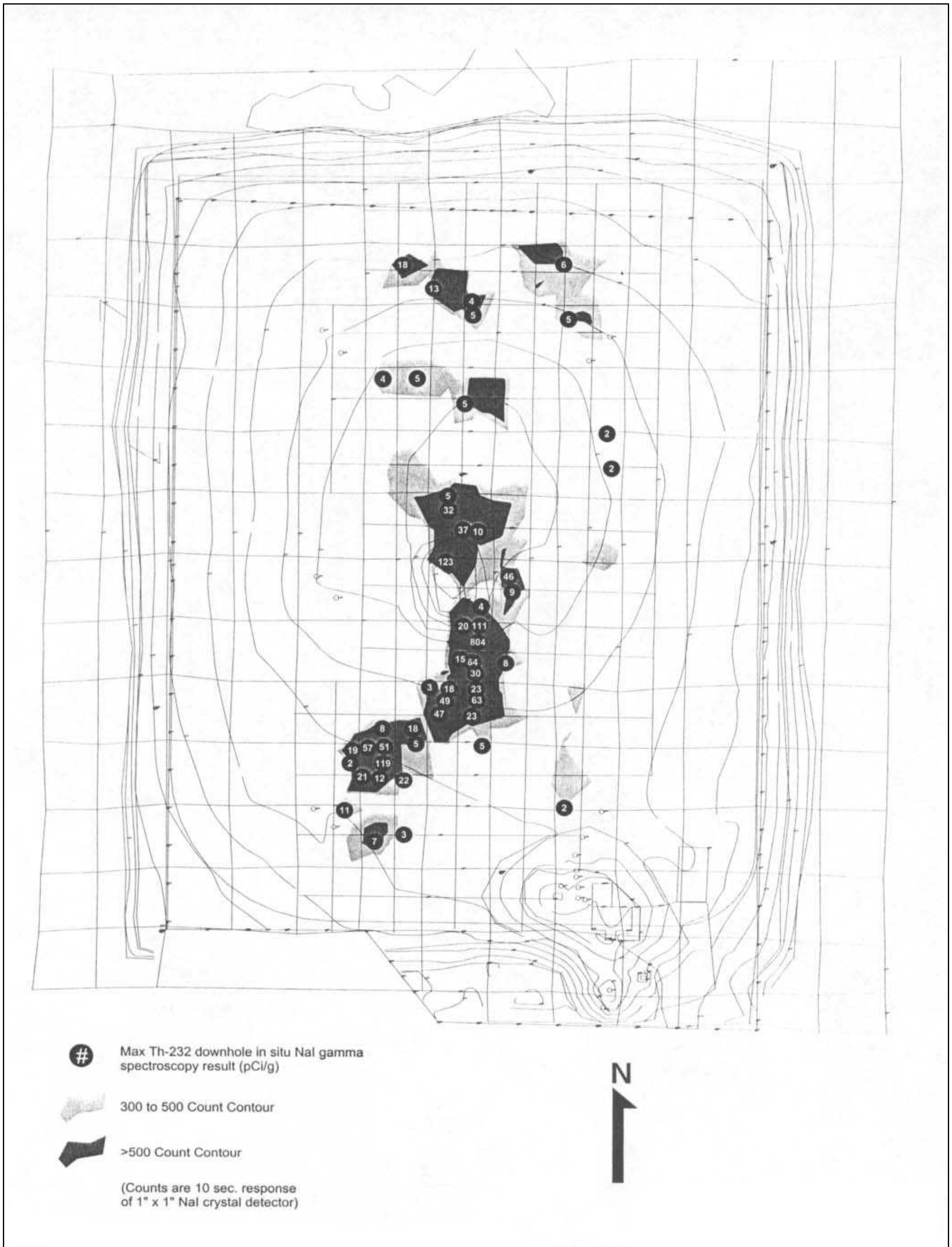

Figure 14–4 Extent of Elevated Radioactivity—In-Situ Gamma Spectroscopy Survey

- 15 sediment samples were taken. The range of Th-232 concentrations was 0.072 to 1.19 with an average of 0.346 pCi/g. The range of Th-230 concentrations was 0.108 to 0.590 with an average of 0.368 pCi/g.
- 9 surface water samples were taken. The range of Th-232 concentrations was 0.012 to 0.065 with an average of 0.032 pCi/L. The range of Th-230 concentrations was 0.021 to 0.129 with an average of 0.054 pCi/L.
- 5 groundwater samples were taken. The range of Th-232 concentrations was 0.025 to 0.100 with an average of 0.053 pCi/L. The range of Th-230 concentrations was 0.084 to 0.190 with an average of 0.131 pCi/L.

These results are consistent with the background measurements reported in the ORAU survey (ORAU 1985) and compare well with values from the literature (ORNL 1980), which indicate a Th-232 concentration range for soils in the State of Michigan between 0.24 and 0.82 pCi/g with an average of 0.56.

14.2.6 Summary of the Radionuclide Composition of Residual Radioactivity at the Site

All of the isotope-specific radiological surveys performed at the site have identified the presence of Th-232 and its radioactive progeny (Figure 14–5). In addition, Th-230 in transient equilibrium with its radioactive progeny has been measured in concentrations well above what might be expected as naturally occurring in typical soils at the site (Figure 14–6).

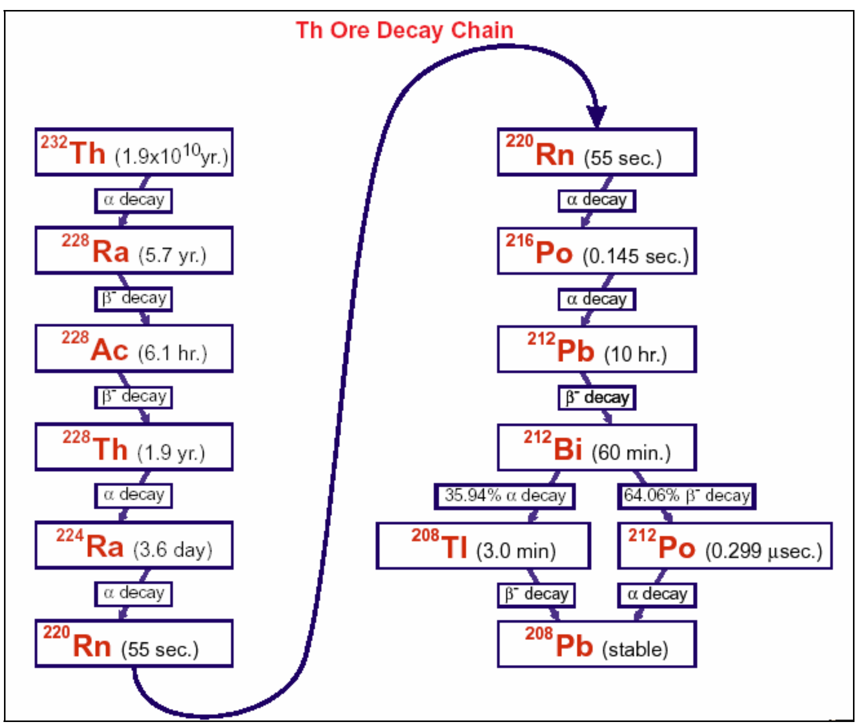

Figure 14–5 Th-232 Decay Series

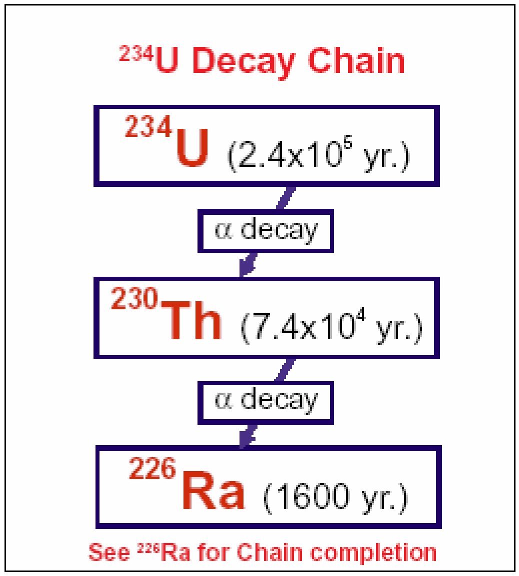

Figure 14–6 U-234 (Th-230) Decay Series

That Th-230 is elevated along with Th-232 in the slag is predictable considering the physio-chemical processes associated with the foundry operations that concentrated thorium and generated the slag.

The radiological characterization survey had as one of its objectives the identification of the radionuclide composition of the residual radioactivity at the site. From the ORAU survey (ORAU 1985), the scoping survey (HLA 1998b), and the characterization survey (Cabrera 2001), it is clearly and consistently reported that Th-232 is present in concentrations above background and in secular equilibrium with its radioactive progeny. However, the concentration relationship between Th-230 and Th-232, and the potential presence of elevated concentrations of Ra-226 and isotopes of uranium are also important to understanding the radionuclide composition of the source term.

A series of 52 subsurface soil samples were collected from across the site and analyzed by an independent offsite laboratory. Selection of the sample locations was guided by the knowledge gained through performance of both of the in-situ surveys described above and biased so as to collect soil samples from locations where the residual radioactivity concentration in soil was likely to be elevated. Each of these 52 samples was analyzed via gamma spectroscopy, and 34 samples were analyzed by alpha spectroscopy for both uranium and thorium-series radionuclides.

Soil sampling confirmed the presence of both Th-230 and Ra-226 in excess of background concentrations. Concentrations of Ra-226, ranging from background to a high of approximately 11 pCi/g, were co-located with elevated Th-230 concentrations, but were only approximately 3-percent of the corresponding Th-230 activity. Given the time elapsed since the slag might have been produced, it is reasonable to conclude that the slightly elevated Ra-226 concentrations present in the slag are the product of the radioactive decay of Th-230 and the resultant ingrowth of Ra-226.

The relationship between Th-230 and Th-232 concentrations in the slag is likely derived from their relative concentrations in the ores from which they were derived. Isotopic thorium analyses indicate that the Th-230 to Th-232 activity ratios are located in clusters, associated with what appears to be two different waste streams. Activity ratios were consistently measured at approximately 1:1 over the majority of the site. However, in two small clusters (one at the north end of the site, the other on the south end) the ratio is approximately 10:1 (See Figure 14–7). The estimated volume of radioactively contaminated material in these two small clusters is diminutive relative to the total volume of material with concentrations in excess of background.

Since the samples from which the isotopic ratios were obtained were not collected using a random sampling method, and because there are evidently two discrete populations with respect to the Th-230:Th-232 ratio, it is appropriate to apply a weighting process to arrive at the best estimate of representative isotopic ratio to be used in dose modeling. The use of volume weighting is particularly appropriate in this case. The volume-weighted Th-230:Th-232 ratio is calculated to be approximately 3.1:1 and is proposed for use in the abstract description of the source term for modeling. Of note, is the fact that there is little implication to the projected annual dose to a receptor exposed at the site arising from the value of the Th-230:Th-232 ratio used in describing the source term for the buried waste layer within the cell. In fact, sensitivity analysis performed using the RESRAD dose model indicates an unremarkable change (increase) in the projected dose from the encapsulated waste layer when the Th-230:Th-232 ratio is set to the maximum ratio measured at the site (11:1).

It had been suggested earlier that concentrations of uranium isotopes might also be considered as a component of the elevated radioactivity in slag materials buried on the site. To assess this possibility, alpha spectroscopy for uranium isotopes was performed on 34 samples collected from locations where the highest in-situ gamma measurements were recorded. The laboratory analytical analyses indicated the presence of U-234, U-235, and U-238 in concentrations comparable to those found in background soils in the vicinity of the site and in U.S. soils in general (Cabrera 2001). Correlation between uranium isotopes and elevated concentrations of thorium isotopes was not observed.

Having considered the analytical evidence for establishing the radionuclide composition of residual radioactivity at the site, the following source term isotopic composition is defined:

- Pb-210 0.5%
- Ra-226 1.1%
- Ra-228 16.1%
- Th-228 16.1%
- Th-230 50.0%
- Th-232 16.1%

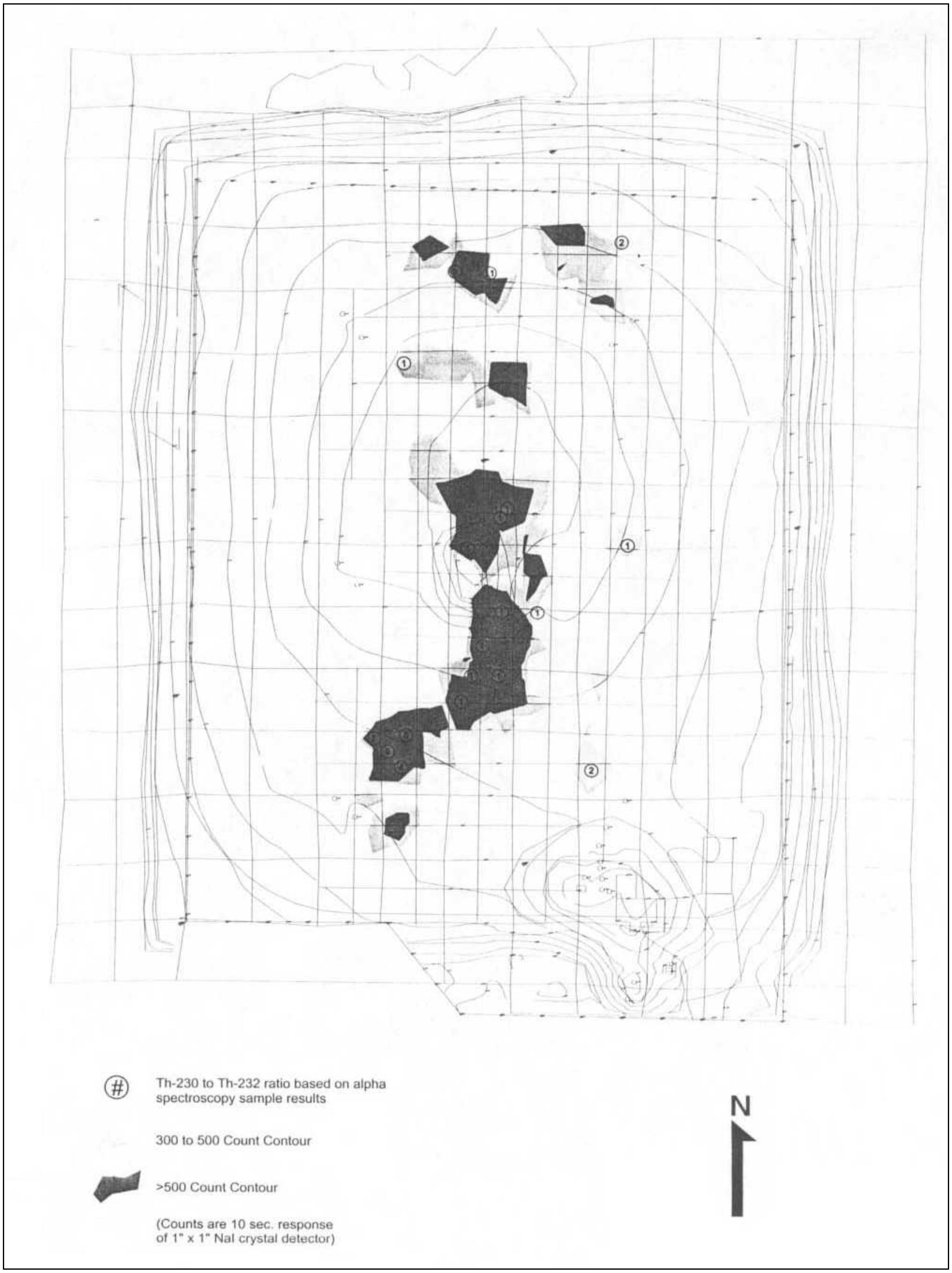

Figure 14–7 Lateral Distribution of Thorium 230:232 Activity Ratios

The isotopic composition proposed is based upon the volume-weighted isotopic ratio between Th-230 and Th-232 as measured on the site (Cabrera 2001). It is assumed that the Th-232 series radionuclides are present in secular equilibrium. The Th-230 was decayed for a period of 50 years to calculate the amount of Ra-226 and Pb-210 progeny ingrowth. The Ra-226 ingrowth activity calculated by decaying Th-230 for 50 years results in a Ra-226:Th-230 ratio that agrees well with that measured (2 to 3-percent). The isotopic ratios used in calculating the projected annual dose to potentially exposed persons is presented in Figure 14–8. The short-lived progeny (those with half-lives less than 180 days) are assumed to be in equilibrium with the parent nuclide and are accounted for in the dose modeling through the RESRAD code's use of "parent +D" dose conversion factors.

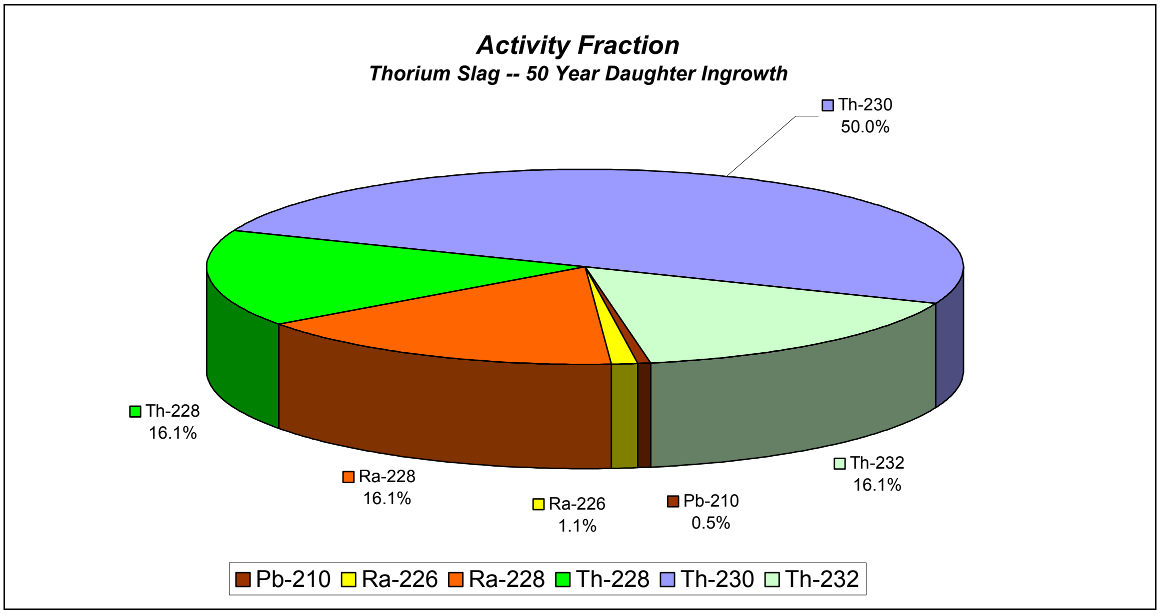

Figure 14–8 Radionuclide Composition of Residual Radioactivity

14.2.7 Depth of Residual Radioactivity in Subsurface Soils

A principle design objective for the radiological characterization survey was to develop a three-dimensional view of the site's residual radioactivity deposition. This was accomplished through the collection of almost 6,000 gross gamma radiation measurements within the GeoProbe® casings emplaced across the site. The lateral placement locations were determined by a systematic grid established with a global positioning satellite (GPS) system. Additional locations were placed in areas where elevated radiation levels were encountered to further resolve the three-dimensional profile. Vertically, measurements were made at 1-foot intervals beginning from a depth of 1-foot below the ground surface (bgs) and proceeding down to the bottom of the casing. Figure 14–9 through Figure 14–12 present plots of gross gamma logging data displayed in vertical cross sections. For reference, the ground surface (the top of the clay cover) is approximately 592 feet above mean sea level. Cross section C–C' is drawn approximately down the path of the former access road through the site, along which radiological surveys have consistently located the elevated radioactivity deposits. This cross section provides the best overall (most representative) two-dimensional view of depth profile.

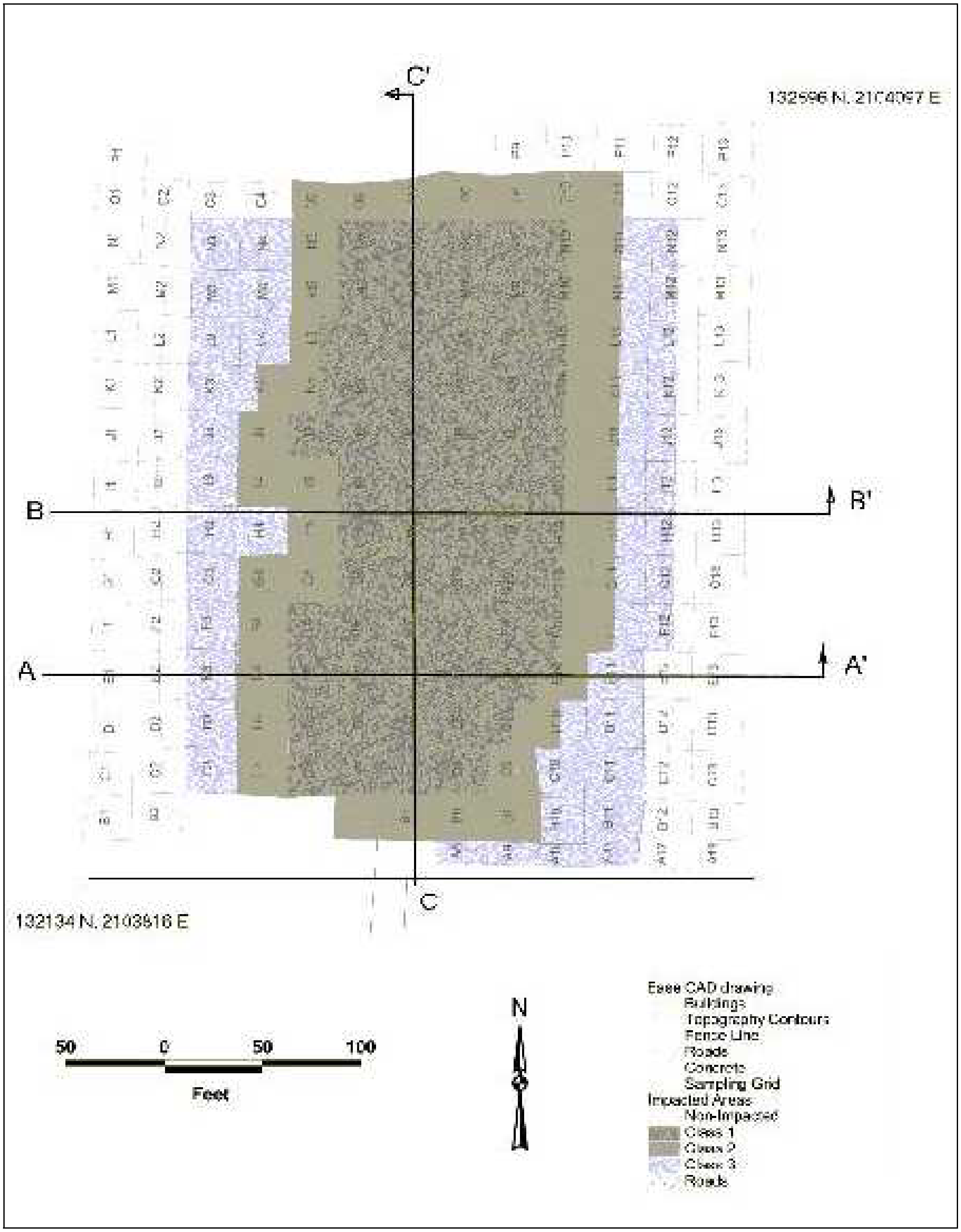

Figure 14–9 Cross Section Locations

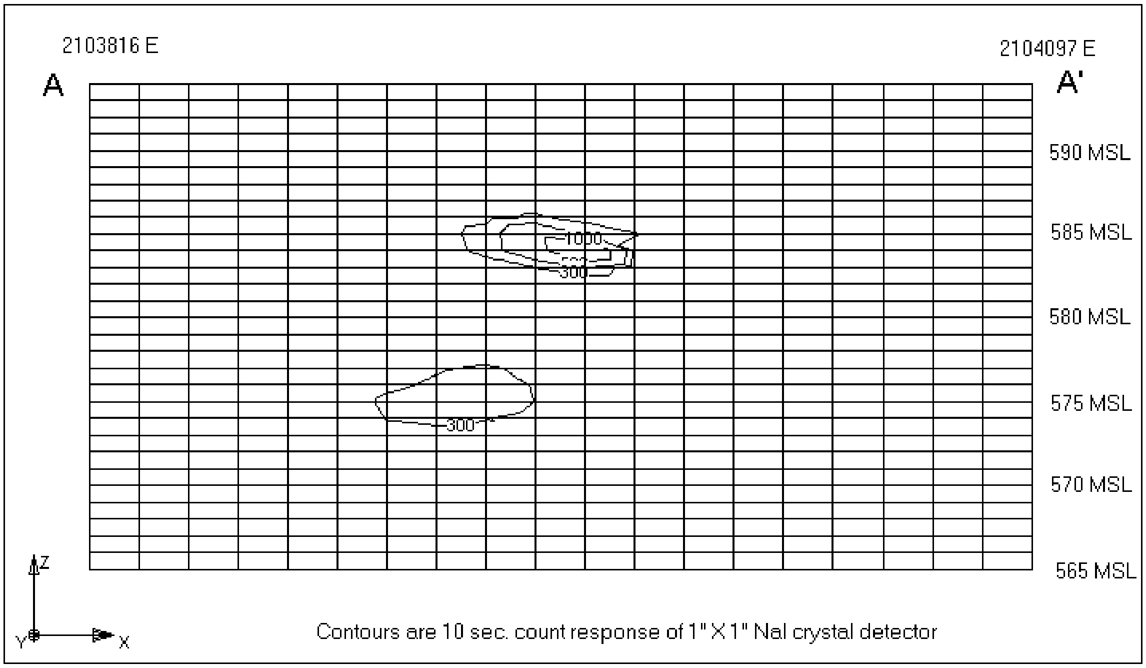

Figure 14–10 Cross Section A-A'

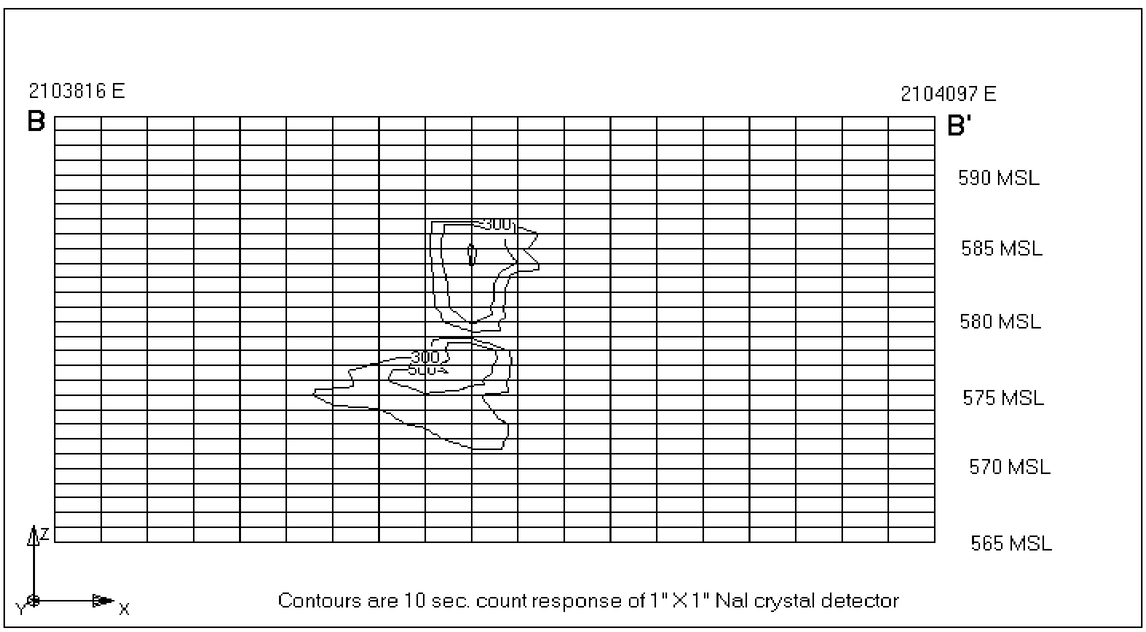

Figure 14–11 Cross Section B-B'

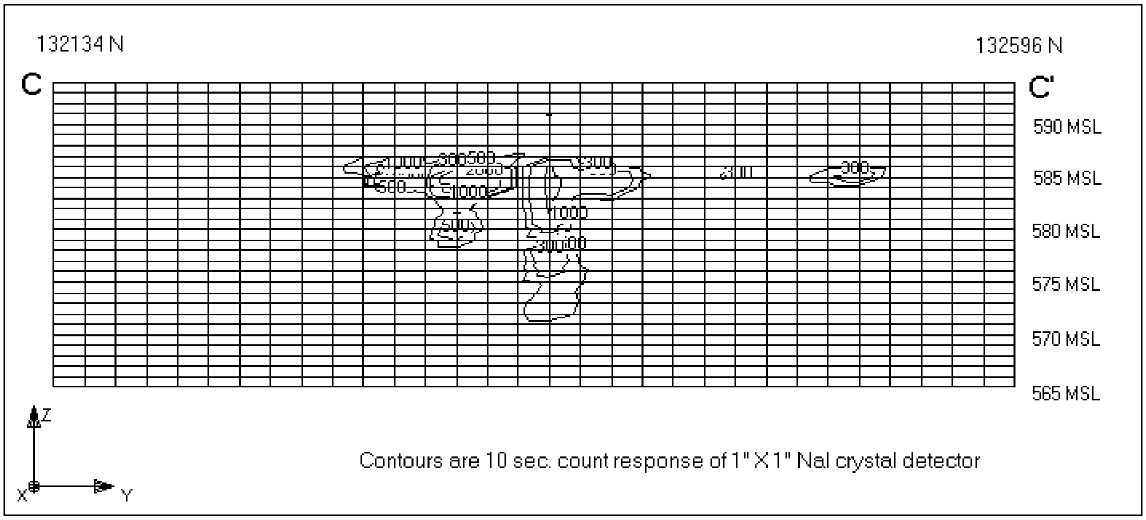

Figure 14–12 Cross Section C-C'

From these figures, it is evident that there are two discrete locations where radioactive slag has been deposited in pockets deeper than a few feet, but elevated radioactivity was confined to depths well above the interface of the clay-bearing till layer underlying the site. It is also evident that the majority of radioactivity is located just slightly beneath the clay cover and within a thickness of approximately 4 feet (1.22 meters).

14.3 REMEDIAL ACTION SUPPORT SURVEYS

Based upon historical and operational knowledge, as well as radiological scoping and characterization surveys performed to date, it is not anticipated that that any remedial action will be required to achieve the proposed DCGLs.

14.4 FINAL STATUS SURVEY DESIGN

This section presents the basic design of the proposed radiological survey (final status survey) intended to demonstrate that the final radiological status of the Tobico Marsh SGA Site complies with the required and approved radiological conditions. The final status survey (FSS) will be designed using the applicable guidance contained in MARSSIM (NRC 2000b). The surveys will provide data to demonstrate that the residual radioactivity in each survey unit satisfies, with acceptable confidence, the applicable release criteria for unrestricted release (Section 14.1). The FSS design was developed using the data quality objective (DQO) process. The application of the seven DQO steps to the design of the FSS is found at the end of Section 14 (Table 14-4).

14.4.1 Buildings and Structures

As described in Sections 8.0 and 14.1.1, MDNR plans to remove the LCTS building and above-grade LCTS piping and appurtenances. These activities are to be performed during the decommissioning process, in advance of achieving the "final condition" of the site at the time of license termination. Consequently, radiological surveys performed in support of this activity are appropriately conducted as materials and equipment surveys rather than an FSS.

14.4.2 Subsurface-Soil Source Term

Given that the potential future annual dose arising from radioactivity in the subsurface soil is physically limited to a value well below the decommissioning dose criterion by the specific activity of Th-232, it is evident that the actual radioactivity concentration in subsurface soil could not exceed the associated $DCGL_W$. Therefore, it is not necessary to perform a radiological survey to demonstrate that the final site condition satisfies the DCGLs and thus the decommissioning standard's annual dose criteria.

14.4.3 Surface-Soil Source Term

The surface soil source term is a hypothetical source term arising from the possibility that subsurface radioactivity may have been brought to the surface and inadvertently deposited on the otherwise radiologically clean surface soil overlying the waste layer during the site characterization survey. The surface soil source term is determined to fit the definition and expectations associated with a *Class 3* area as described in MARSSIM (NRC 2000b). As such, there is no practical limit to the MARSSIM-suggested areal size of a FSS survey unit, and MDNR proposes to evaluate the surface soil source term as a single *Class 3* survey unit. The potentially impacted surface soils are defined as those lying within the area circumscribed by the slurry walls of the cell (Figure 14–13). Residual radioactivity, either surface or subsurface, has never been found outside of the slurry wall boundary.

The areal distribution of the surface soil source term is related to the areal distribution of the subsurface deposits. However, the probability that residual radioactivity is as widely distributed in surface soils as it is in subsurface soils is exceedingly small. The very nature of deposition mechanism hypothesized supports the idea that if a measurable amount of radioactivity were brought to the surface, it would be confined to a relatively localized area near the corehole placement. In addition, it is reasonable to conclude that residual radioactivity deposition in surface soils might possibly occur only around a fraction of the coreholes in which measurable subsurface radioactivity was detected (Figure 14–14). This scenario presents somewhat of a challenge to the typical survey design described in MARSSIM.

Simply collecting and analyzing a set of random surface soil samples over the engineered clay cover might provide the needed assurance that the average residual radioactivity concentration in surface soils meets the applicable $DCGL_W$. However, a simple random sample would, in all likelihood, miss sampling the surface soil in the immediate vicinity of former coreholes—the soil with the greatest potential to have been contaminated by the core sampling. It would also fail to provide the data needed to definitively address the hypothesis posed by the NRC: "…that there is a potential that [radioactive] contamination was brought up to the surface following recent characterization work."

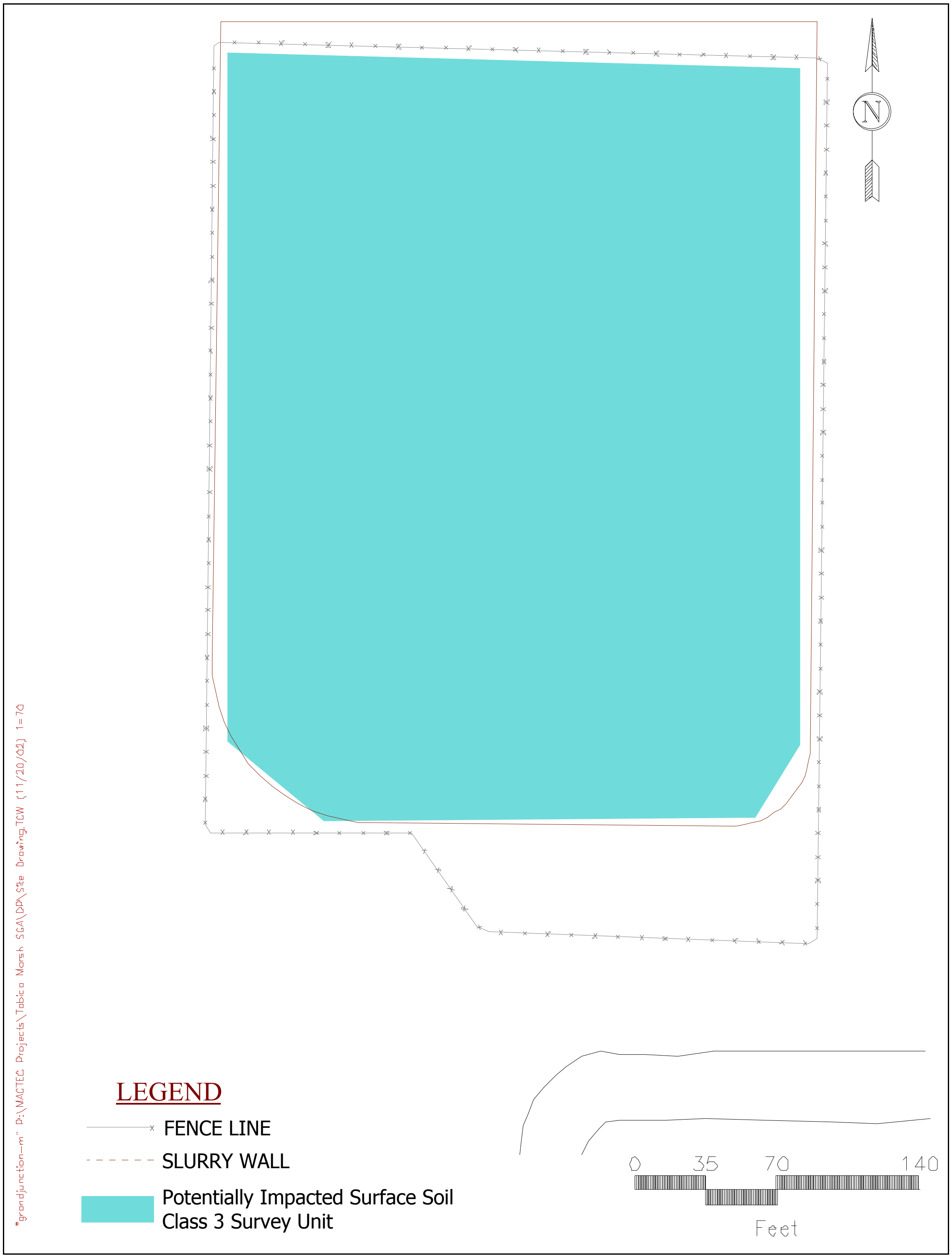

Figure 14–13 Potentially Impacted Surface Soil Area

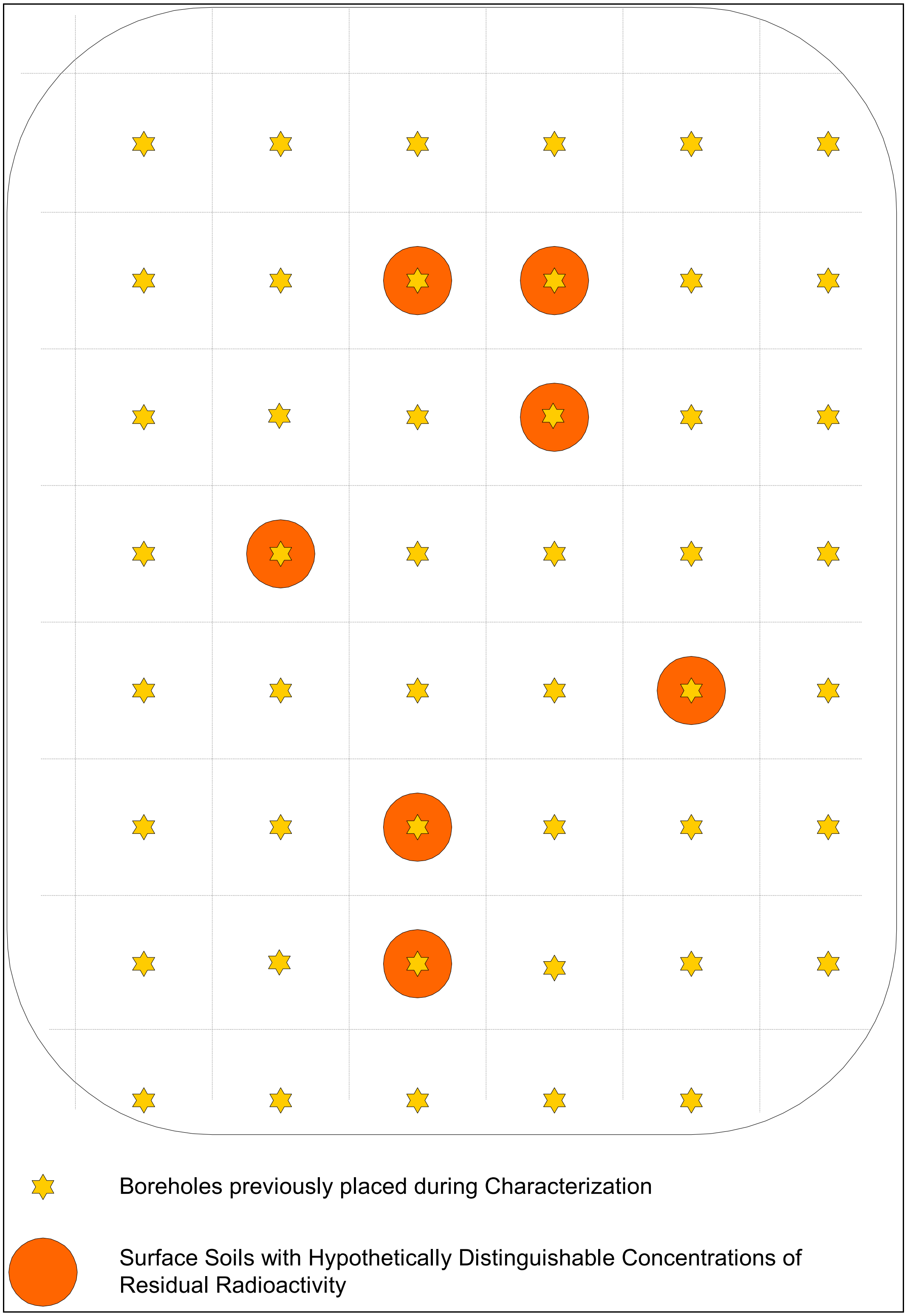

Figure 14–14 Hypothetical Surface Soil Source Term Areal Distribution

To address this hypothesis, a two-sample comparison is needed. The basic objective of such a test is to determine whether there is a statistically significant difference between the concentrations of radioactivity in surface soils in the area immediately surrounding the former coreholes and comparable surface soils that are known to be unimpacted by radioactivity from licensed activities (a reference area).

The next design consideration to be dealt with is the absence of a classically defined and comparable "reference area" against which a comparison can be established. The engineered clay cover material was imported to the site from a local borrow area. The clay materials used are native to the region. Deposits of similar materials can even be found at the site, underlying the Belleville soils and beach sand deposits, but not on the surface. Nonetheless, given the question at hand, and the fact that MDNR has developed a surface soil DCGL, a solution that addresses the hypothesis posed and provides the data needed to demonstrate that the DCGL, has been met is available.

If, in fact, radioactivity in subsurface soils were brought to the surface during characterization sampling and left there, one would expect to find elevated concentrations in the immediate vicinity of the corehole but essentially background concentrations at locations furthest away from (interstitial to) the coreholes. This expectation is further supported by the knowledge that plastic sheeting was used on the ground around the corehole locations specifically to protect the ground surface from becoming contaminated. With this in mind, the surface soil survey unit can be subdivided into two strata. One stratum (Stratum A) is defined by a small, 1.0-meter diameter circle centered over the former coreholes. The other stratum (Stratum B) serves as a quasi-reference area and is defined as the remaining area outside the 1.0-meter diameter circle describing the first stratum (Figure 14–15).

The sample design incorporates a process in which random sampling is used to select the 1.0-meter diameter circles in Stratum A to be sampled and a separate random placement of an equal number of samples to be located in Stratum B (Figure 14–16). The top veneer of the surface soil will be sampled within a 1-meter-diameter area around the selected corehole of Stratum A or random sample location for Stratum B. Soil samples will be analyzed by an independent contract laboratory. After results are obtained, an appropriate two-sample statistical test, such as the "Wilcoxian Rank Sum" (WRS) or "Two-Sample Sign" test, will be employed to discern whether the concentrations of radioactivity in the two samples are different from one another by a statistically significant margin (See the DQO summary in Table 14–4). If the samples from the two strata are different from one another by a statistically significant margin, it can be concluded that some amount of subsurface radioactivity was indeed brought to the surface during prior characterization activities.

The second objective of the sampling design is to produce a data set that can be used to discern whether the concentration of residual radioactivity in surface soils (if it is found to be present) exceeds the proposed $DCGL_W$. MDNR proposes that the same sample data collected from Strata A and B in the surface soil survey unit be used for this purpose.

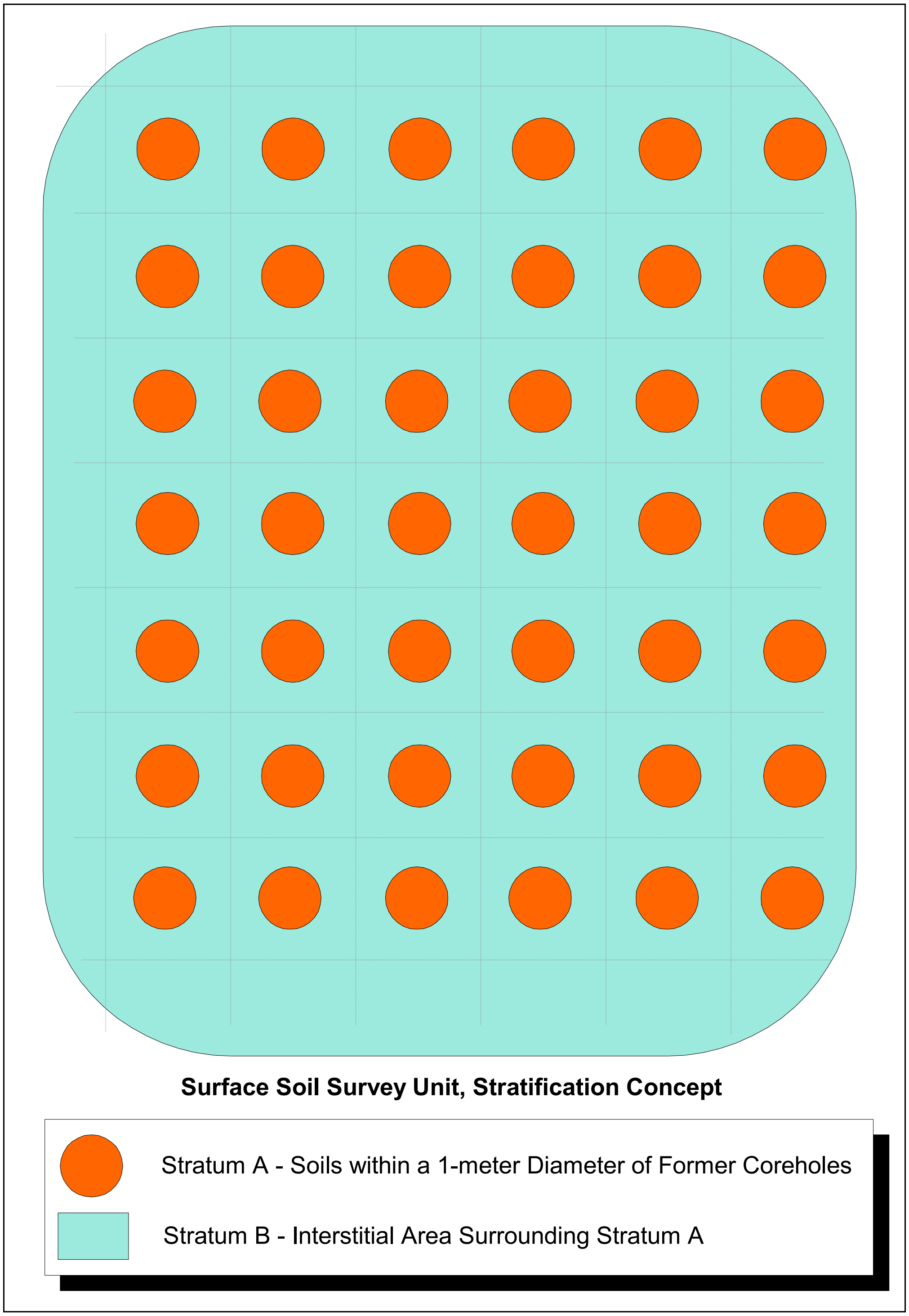

Figure 14–15 Surface Soil Survey Unit, Stratification Concept

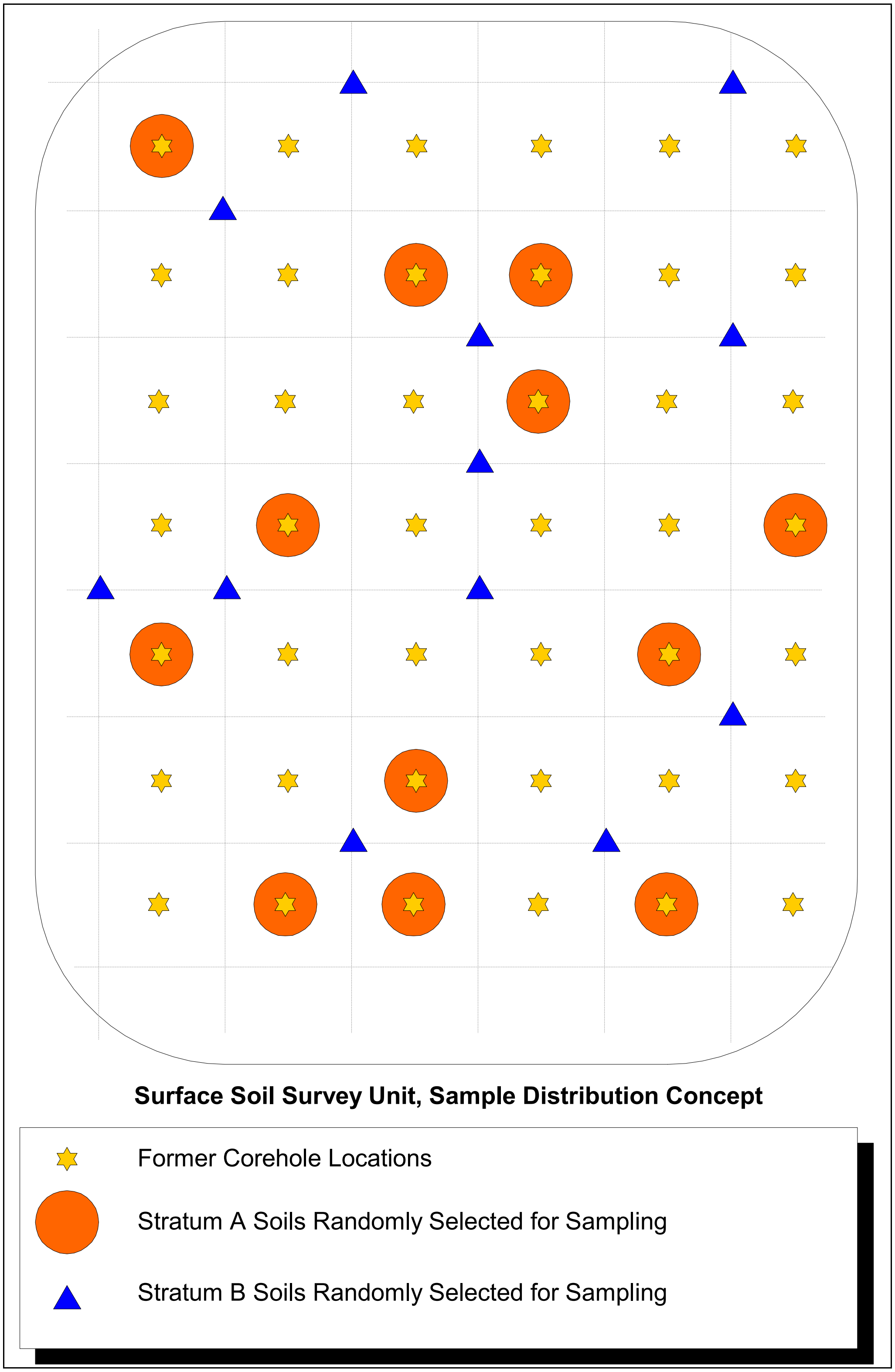

Figure 14–16 Two-Sample Conceptual Design

MDNR is confident that radiological controls in place during characterization were effective in precluding the release of significant amounts of radioactivity during characterization sampling. Consequently, MDNR believes that there is little chance that that the results from samples collected in Stratum A alone would exceed the proposed surface soil $DCGL_W$, and proposes that the Stratum A and Stratum B sample data be compared independently to the $DCGL_W$ for surface soils using an appropriate single sample statistical test, such as the Single-Sample Sign test.

This treatment of the data is conservative by design in that the dose modeling used to derive the surface soil $DCGL_W$ does not benefit from the systematically distributed nature of the soils in Stratum A, assuming of course that there is any distinguishable difference between concentrations of radioactivity in Strata A and B. Addressing the potentially significant conservative bias introduced, MDNR further proposes to pool the data from the two strata into a single sample set that will again be compared to the $DCGL_W$ for surface soils using an appropriate single-sample statistical test, such as the Sign test.

14.4.4 Summary of Statistical Tests

Measurements from the surface soil-survey unit will be compared statistically to the appropriate $DCGL_W$. In general, non-parametric statistical tests of two types will be employed in evaluating compliance for final status survey: a one-sample test (such as the Sign test) or a two-sample test (such as the WRS test, sometimes called the Mann-Whitney test). A one-sample test compares the sample results directly to the release standard, whereas a two-sample test seeks to determine whether there is a statistically significant difference between the two samples. In the case of a two-sample test, the surface soil sample data set from Stratum A is compared to the essentially equivalent data set from Stratum B. In this case, the two-sample test will be used to determine whether there is a distinguishable difference between Strata A and B, thus answering the fundamental question: *Has the surface soil been impacted with residual radioactivity brought to the surface during characterization sampling?* It will not, in this case, be used to indicate whether the survey unit exceeds the reference area by more than the $DCGL_W$ (the classic MARSSIM application of the WRS test).

In addition, an elevated measurement comparison (EMC) will be performed against each individual surface soil sample data point to ensure that the measurement result does not exceed the specified investigation level (the $DCGL_{EMC}$). If any measurement exceeds the $DCGL_{EMC}$, then additional investigation will be initiated regardless of the outcome of the statistical test of the central tendency value.

14.4.5 Direct and Removable Measurements

Direct-scanning measurements of the ground surface using a beta/gamma “pancake” Geiger-Mueller (GM) detector will be made within the 1-meter-diameter area of the Stratum A locations selected for sampling. The objective of the scanning measurements is to locate discrete spots on the surface within the sample area where elevated concentrations of radioactivity might be present. In this way, the sampler will be able to qualitatively assess the radiological condition of the surface soil and include surface soils exhibiting potentially elevated concentrations of radioactivity in the collected soil sample.

The scanning instrument to be used is a typical field-portable beta/gamma pancake GM detector and instrument (Table 10-3). This instrument is selected because the contaminants present at the site emit a relatively strong and readily detected beta signal and because the sensitivity of the pancake GM detector to relatively minor variations is superior to that of a gamma-sensitive detector such as a sodium-iodide detector. The beta-radiation signal is also significantly less prone to self-shielding than the alpha signal also emitted by the contaminants present at the site. The instrument will be calibrated at least annually and operationally tested each day prior to use as described in Sections 10 and 13 of this DP.

Removable surface activity measurements are not appropriate for this survey design as there is no appropriate DCGL for comparison and because the measure of contaminant mobility in the environment has already been accounted for in the dose modeling used to derive the $DCGL_W$.

14.4.6 Sampling

As described, the design for the FSS of the surface soils uses surface soil sampling as the principle source of data. Surface soil samples will be collected from the uppermost 0- to 5-cm layer of soil in the randomly selected sample areas of Strata A and B. One liter of sample material will be collected from each sample location. Where split samples are specified, two liters of soil will be collected from the designated area and then blended in the field to improve the homogeneity of the sample before being split into separate sample containers.

Samples will be submitted to an appropriately licensed, independent, contract laboratory for analysis by gamma spectroscopy and by alpha spectroscopy for thorium. Contract required detection limits (CRDL) will be established to ensure that method detection limits of at least 3 pCi/g for Th-232 are achieved. A method detection limit of 3 pCi/g for Th-232 is a very small fraction of the surface soil $DCGL_W$. Both gamma and alpha spectroscopy laboratory analyses are typically capable of achieving detection sensitivities at least as low as 3 pCi/g.

14.4.6.1 Control and Handling of Samples for Laboratory Analysis

Sample collection, handling, control, and laboratory analyses will be conducted in accordance with written procedures. Soil samples collected will be hand-blended and sieved in the field to remove debris or large stones that might be present, and which might, otherwise, bias the analytical results. Soil samples will be uniquely labeled in the field and linked to a site map to ensure traceability of the sample results with the sample location. The contractor's chain-of-custody procedures will be used to ensure integrity of samples and data from sample collection through data reporting.

14.4.7 Final Status Survey Investigation Levels

The only investigation level established for the FSS is the $DCGL_{EMC}$, which has been established at the $DCGL_W$ value of 357 pCi/g (Th-232) as described in MARSSIM (Roadmap, Table 5). A value smaller than the $DCGL_W$ is not warranted as a designed investigation level since the design of the survey is already substantially biased toward finding the highest concentrations of radioactivity in surface soil. It is biased not only by the subdivision of the survey unit into two discrete strata, but also by the use of direct surface scanning measurements within selected Stratum A areas to bias the sample to contain surface soil emitting the highest beta/gamma radiation levels.

14.4.8 Significant Radioactivity Previously Unaccounted

Based upon the radiological surveys performed to date, there is no expectation of significant additional radioactivity at the site that has not been accounted for. Routine surveys and investigations performed since the completion of the last major characterization surveys (Cabrera 2001) have not revealed the presence of previously unaccounted radioactivity.

14.4.9 Data Used to Estimate Survey Unit Parameters

The previously described data characterizing the radiological conditions of the site (Section 14.2) form the basis for the demarcation and selection of survey units for the FSS as well as the anticipated parametric features of the distributions of data describing the concentration of residual radioactivity. It has been shown that the subsurface soil source term cannot reasonably produce an annual dose approaching the decommissioning dose limit even if the Th-232 activity were present at its specific activity limit. Consequently, there is no need to establish survey units or anticipate the parametric features describing its radiological condition.

As for the surface soil source term, the survey unit demarcation and classification has been extensively described and supported above. Since the subsurface characterization activity, there has been no collection of quantitative surface soil characterization data upon which survey unit demarcation or classification might be based. However, the periodic general-area gamma-radiation surveys performed at the site, as well as a recently performed beta/gamma scan survey of surface soils around biased coreholes, provide solid qualitative evidence that was used to demarcate and classify the survey unit.

Based on the lack of discernable variability in the beta/gamma radiation levels observed in the surface soil scan survey around the coreholes, it is not anticipated that large variance will be observed in the surface soil survey unit during the FSS. While the magnitude of variance is expected to be quite small, particularly in light of the $DCGL_W$, the coefficient of variation might actually be relatively large, as it tends to be when sampling environmental concentrations of naturally occurring radionuclides. This phenomenon occurs when the constituent being measured is present in background at a relatively low concentration but has a relatively large natural variability. It is frequently encountered when measuring media that have little or no added radioactivity but in which concentrations of natural uranium or thorium are present.

14.5 FINAL STATUS SURVEY REPORT

MDNR has planned and committed resources for the creation of an FSS report documenting the results of the FSS. The FSS report will be submitted to the NRC separately as the decommissioning process approaches completion.

Table 14–4 FSS Data Objective Summary

DQO Element			Remark
1	Problem Statement	The MDNR seeks to decommission the parcel of property known as the Tobico Marsh SGA site and terminate the radioactive materials license associated with the site. The site (currently owned by the State of Michigan) was formerly used as an industrial waste disposal site as part of the former Hartley & Hartley landfill. Aside from non-radioactive industrial wastes, the site was used to dispose of foundry slag wastes, some of which has elevated concentrations of naturally occurring radioactive thorium. In order to contain the non-radioactive potentially hazardous substances that had been disposed there, a slurry wall of high clay content material was installed to completely enclose the deposits and an engineered clay cover caps the site. The radioactive thoriated slag exists in deposits in subsurface soils (beneath the clay cover) at the site. It has also been hypothesized that prior characterization sampling activities at the site might have brought subsurface radioactivity to the surface resulting in surface deposits of residual radioactivity. In order to demonstrate compliance with the U.S. NRC criteria for decommissioning of the site, it is necessary to design a Final Status Survey Plan that assesses whether the residual radioactivity associated with thoriated slag in soil is below the concentrations considered safe for future unrestricted use of the site. It is known, based upon dose modeling alone, that the subsurface soil source term cannot reasonably result in a dose to a future receptor at the site that exceeds the decommissioning criteria of 25 mrem/y. The surface soils, on the other hand, could possibly contribute a dose that exceeds the decommissioning criteria, if it was found that significant quantities of radioactivity were indeed brought to the surface.	Historical information and site characterization data confirm that the MDNR site was used to dispose of foundry slag wastes, some of which are concentrated in naturally occurring radioactive thorium. As a result of these characterization activities, residual radioactivity in surface soil could possibly exist in concentrations that may pose an unacceptable hazard from exposure to persons occupying or using this site in the future. To decommission the site and terminate the site's NRC radioactive materials license, the site must be shown to be radiologically safe for future use by demonstrating that the NRC's decommissioning criteria for release from radiological controls without restriction have been met. A site-specific DCGL for Th-232 in surface soil has been developed for the site (see Section 5.0). The site-specific DCGL has been derived considering the basic public dose-limit and other applicable Federal, State, and local requirements. The DCGLs are based on the observed site-specific radionuclide data and historical information that confirm thoriated slag to be the contributing source of residual radioactivity at the site. The objective of the Final Status Survey is to quantitatively demonstrate that Th-232 is not present in surface soils on the site in concentrations greater than the site-specific DCGLs.
2	Decisions to Be Made	Is there sufficient evidence from surface soil radiological data collected at the site to demonstrate that the site can be released from radiological controls without restriction on its future use? Is it feasible to further reduce the concentrations of residual radioactivity in soils at the site to levels below those necessary to meet the applicable soil DCGLs (i.e., ALARA) considering the overall cost vs. benefit of additional remedial efforts?	The decisions to be made are inclusive of the decision bases for the NRC decommissioning criteria for radiologically impacted sites.
3	Decision Inputs	Specific decision input information: • An estimate of the central tendency (median)[a] concentration of Th-232 radioactivity in soil (pCi/g) in each of Strata A & B of the surface soil survey unit. • An estimate of the central tendency (median)[a] concentration of Th-232 radioactivity in soil (pCi/g) in the surface soil survey unit obtained by pooling sample data from Strata A & B. • An evaluation of the possibility of regions with locally elevated concentrations of residual radioactivity in soil that could pose a significant hazard to exposed individuals. • An ALARA benefit/cost effectiveness analysis. These decision inputs will be obtained directly from data developed in the conduct of the Final Status Survey.	The site-specific surface soil DCGL was developed using extensive dose analysis information to arrive at the candidate Th-232 DCGLs. The future use scenario resulting in the most limiting candidate DCGL was the Composite Recreational User scenario, which yielded a $DCGL_W$ of 357 pCi/g Th-232 to the average member of the critical exposure group.
4	Study Boundaries	The study encompasses surface soils of the potentially impacted area within the region circumscribed by the slurry walls. The potentially impacted surface soil area lies completely within the fenced area of the site (See Figure 14-13). The study does not include subsurface soils or areas outside the region circumscribed by the slurry walls and designated as non-impacted. It also does not include buildings, structures, or non-real property as these are planned to be removed prior to achieving the final site condition prior to license termination.	The scope of the Final Status Survey is to address the possibility that subsurface radioactivity might have been brought to the surface during previous characterization activities and to address the possibility that concentrations of residual thorium radioactivity in surface soils of the site might pose an unacceptable human health hazard at the completion of planned decommissioning activities. Previously completed characterization surveys have ruled out the potential for site related radioactivity to be present outside of the slurry walls of the disposal cell or the existing fence line around the site. Site-specific dose modeling rules out the reasonable possibility that deposits of thorium-bearing slag contained within the cell might produce an annual dose approaching the decommissioning standard's annual dose limit under conditions of unrestricted use. In fact, the existing fence line has been adjusted specifically, in some cases, to demarcate areas where residual depleted uranium radioactivity in soil had previously been identified.
5	Decision Rule(s)	**IF** the evaluation of the Final Status Survey data indicates that the residual Th-232 concentration in surface soil in Stratum A cannot be statistically distinguished as significantly greater than the residual Th-232 concentration in surface soil in Stratum B, **THEN** conclude that subsurface radioactivity was not brought to the surface and deposited during prior characterization activities at the site. **IF** the evaluation of the Final Status Survey data indicates that: • The average (median)[a] residual Th-232 concentration in soil in Stratum A is less than 357 pCi/g; **AND** • The average (median)[a] residual Th-232 concentration in soil in the surface soil survey unit (Strata A & B data sets pooled) is less than 357 pCi/g; **AND** • There are no areas having locally elevated concentrations of residual radioactivity in soil in which the average (median)[a] residual radioactivity concentration of Th-232 is greater than the $DCGL_W$ (357 pCi/g) when averaged over an area of $1m^2$; **AND** • The cost benefit analysis indicates that residual radioactivity in surface soils at the site has been reduced to concentrations that are ALARA; **THEN** conclude that the site meets the criteria for release from radiological controls without restriction.	The Th-232 in surface soil $DCGL_W$ for the site is 357 pCi/g. In keeping with its designation as a Class 3 survey unit, surface soils are not expected to have significant concentrations of radioactivity above naturally occurring background levels. The $DCGL_{EMC}$ has been set equal to the $DCGL_W$. Individual samples and measurements will be compared with the $DCGL_{EMC}$ (= $DCGL_W$). Individual samples and measurements having Th-232 activity exceeding the $DCGL_{EMC}$ value will be flagged for additional investigation and sampling.

<table>
<tr><th colspan="9">DQO Element</th><th>Remark</th></tr>
<tr><td rowspan="6">6</td><td rowspan="6">Decision Uncertainties</td><td colspan="7">The following quantitative factors will be integrated into the data collection plan:

True state of nature, Hø, (null hypothesis):

1. The average (median)[a] Th-232 concentration in surface soils of Strata A and B are equal.

2. The average (median)[a] Th-232 concentration in surface soils of Stratum A exceeds the $DCGL_W$.

3. The average (median)[a] Th-232 concentration in surface soils of the surface soil Survey Unit (Strata A & B data pooled) exceeds the $DCGL_W$.

4. The average (median)[a] Th-232 concentration in surface soils in an area having locally elevated concentrations exceeds 357 pCi/g when averaged over $1m^2$.</td><td rowspan="6">The selection of the “true state of nature, Hø,” (null hypothesis) that Th-232 radioactivity in soil is present in concentrations exceeding the $DCGL_W$ at the site is the conservative form of the null hypothesis. It places the burden on MDNR to demonstrate that there is clear and significant evidence to support a conclusion that the average (median) residual radioactivity concentration in surface soil is less than the $DCGL_W$.

A Type I error would occur if it were determined that the average (median) residual Th-232 concentration in surface soil is less than the $DCGL_W$ (357 pCi/g) when, in fact, it is greater. A Type II error would occur if it were determined that the average (median) residual Th-232 concentration in surface soil is greater than the $DCGL_W$ (357 pCi/g) when, in fact, it is lesser.

The comparatively low Type I error rate of 5% (assumed for all cases) is consistent with standard industry practice and reflects MDNR’s concern that important decisions such as this be based upon clear evidence derived from sufficient sampling data. Regulatory agencies typically adopt decision levels based on Type I error rates of 5 to 10% to ensure protection of public health and the environment.

In general, a decision level based on lower Type I & II error rates prompts more sampling and surveying to achieve statistical certainty. MDNR’s selection of a decision level for locally elevated concentrations in excess of the $DCGL_{EMC}$ based on a 25%Type II error rate reflects the need to control sampling costs and MDNR’s inclination to remediate areas, if necessary, having locally elevated concentrations of Th-232 in surface soil even though the survey unit average concentration is below the $DCGL_W$.

The four-part hypothesis reflects MDNR’s concern not only to adequately quantify the average (median) Th-232 radioactivity concentration in surface soil, but also acknowledges the unique distributional circumstances presented by the systematic grid of coreholes placed during subsurface characterization activities, and establishes the decision basis for quantifying locally elevated concentrations of radioactivity in discrete areas. The fourth part of the hypothesis (dealing with areas having locally elevated concentrations of residual radioactivity) is applicable only if concentrations of Th-232 in surface soil exceed the $DCGL_W$ value, 357 pCi/g.</td></tr>
<tr><td colspan="7">Decision Error Limits[b]</td></tr>
<tr><td colspan="2">Case</td><td>Action Level</td><td>(Type II, β) error rate</td><td>Width of Gray Region</td><td>(Type I, α) error rate</td><td>Remark</td></tr>
<tr><td>1</td><td>Comparison of the average (median) residual uranium radioactivity concentrations in Strata A & B.</td><td>NA</td><td>.05</td><td>NA</td><td>.05</td><td>A one-sided test of the hypothesis is warranted since we are interested only in knowing whether the Th-232 concentration in Stratum A is significantly greater than that in Stratum B.</td></tr>
<tr><td>2
&
3</td><td>Average (median) residual uranium radioactivity concentration in soil.</td><td>357 pCi/g</td><td>0.05</td><td>100 pCi/g</td><td>0.05</td><td>A type I error rate of 0.05 assures that the there is an acceptably small probability that the survey data will indicate that the average (median) residual uranium radioactivity concentration in a survey unit is less than the $DCGL_W$ when in fact it is greater than the $DCGL_W$.</td></tr>
<tr><td>4</td><td>Average (median) residual uranium radioactivity concentration in soil in a locally elevated area.</td><td>357 pCi/g</td><td>0.25</td><td>200 pCi/g</td><td>0.05</td><td>Comparatively higher Type II decision error and larger width of gray region reflects MDNR’s inclination to remediate areas having locally elevated concentrations of radioactivity.</td></tr>
<tr><td>7</td><td>Optimize the Design</td><td colspan="7">The design of the Final Status Survey Plan has been optimized through the consideration and evaluation of the results of previously collected radiological survey and sampling data and by selecting decision error limits that reflect the reasonable likelihood that survey unit average (median) concentrations and locally elevated concentrations of residual depleted uranium activity might occur.</td><td>The survey design seeks to take maximum advantage of the data needs required to address the two key questions posed, through the use of a stratified sampling design that uses the same data (albeit conservatively biased) for addressing the decommissioning criteria.</td></tr>
</table>

a While the DCGLs have been expressed as the average or mean concentration, a skewed distribution (such as is expected when measuring environmental levels of radionuclide activity) or the use of a single sample, non-parametric, statistical test (such as the Sign Test) indicates the use of median as the appropriate metric for comparison to the DCGL. MDNR is aware of the distinction between the mean and the median.

b It is recognized that a failure to adequately assess measurement uncertainty and sample variation could result in statistical power. However, the data quality analysis (DQA) process will assess the actual power achieved considering the magnitude of the average (median) and coefficient of variation (CV) versus the DCGL for the sample size actually collected. Since the null hypothesis for cases 2, 3, and 4 presumes that residual radioactivity concentrations in the survey unit exceeds the DCGL, a lack of sufficient statistical power will result in a greater probability of false positive (Type II) errors (determining that Th-232 concentrations in surface soil exceed the DCGL, when in fact they are less than the DCGL) and a more conservative rather than a less conservative decision basis. If retrospective power computations reveal unacceptable confidence, MDNR will determine if additional sampling is warranted in order to attempt to release the surface soil survey unit.