# 8.0 INTERPRETATION OF SURVEY RESULTS

This Section describes methods for converting survey data to appropriate units for comparison with guideline values and evaluating data, relative to conditions, established for termination of the license. A flow diagram (Figure 8-1) and checklist are provided at the end of this Section to assist the user in these operations.

## 8.1 Data Conversion

Radiological survey data is usually obtained in units, such as counts per unit time, which have no intrinsic meaning relative to the guideline values. Therefore, the survey data from field and laboratory measurements are converted to units which will enable comparisons. Standard units used for expressing final status survey findings are:

- Surface Contamination — $\frac{dpm}{100\ cm^2}$ (disintegrations per minute per 100 $cm^2$)
- Soil Radionuclide Concentration — pCi/g (picocuries per gram)
- Exposure Rate — $\mu$R/h (microroentgens per hour)

In performing the conversions it is necessary to know several factors; these are:

| | |
|---|---|
| c | total integrated counts recorded by the measurement |
| c/m | total countrate from an analog (rate) instrument |
| t | time period (minutes) over which the count was recorded |
| B | count during recording period, due only to background levels of radiation |
| B/m | background count rate on an analog instrument |
| E | detection efficiency of instrument in counts per disintegration |
| A | active surface area of the detector in $cm^2$ |
| M | mass of sample analyzed in grams |
| 2.22 | factor to convert a disintegration rate to activity units of picocuries, i.e. dpm/pCi. |

These factors are used in the equations in the remainder of Section 8.1.

### 8.1.1 Surface Activity

A measurement for surface activity is performed over an area, represented by the sensitive surface area of the detector. If the instrument display is in count rate, i.e. counts per minute, the conversion to dpm/100 $cm^2$ is performed by:

$$\frac{dpm}{100\ cm^2} = \frac{(c/m - B/m)}{E}\left(\frac{100}{A}\right) \qquad (8\text{-}1)$$

For a technique using an integrated count on a digital instrument the conversion is:

$$\frac{dpm}{100\ cm^2} = \frac{(c-B)}{t \bullet E}\left(\frac{100}{A}\right) \qquad (8\text{-}2)$$

The level of removable activity collected by a smear is calculated in the same manner, except, the detector area correction factor, $\frac{100}{A}$ , is dropped from the equation because the smear is performed over a 100 $cm^2$ area and the detector area correction is usually considered when determining the efficiency, leaving:

$$\frac{dpm}{100\ cm^2} = \frac{(c-B)}{t \bullet E} \qquad (8\text{-}3)$$

### 8.1.2 Soil Radionuclide Concentration

To determine the radionuclide concentration in soil in units of pCi/g the calculation performed is:

$$pCi/g = \frac{(c-B)}{t \bullet E \bullet 2.22 \bullet M} \qquad (8\text{-}4)$$

If the analytical procedure includes a wet chemistry separation, it will also be necessary to correct for the fractional recovery (R), determined by a spike or tracer added to the sample.

$$pCi/g = \frac{(c-B)}{t \bullet E \bullet 2.22 \bullet M \bullet R} \tag{8-5}$$

### 8.1.3 Exposure Rate

If an instrument, such as a pressurized ionization chamber or a "micro-R" meter is used for measuring exposure rate, the instrument reading will be directly in the desired exposure rate units of μR/h. A gamma scintillation or GM detector with a count rate or digital scaling instrument provides data in units of counts per minute or per some preset time, respectively. Conversion to μR/h is accomplished, using calibration factors developed for the specific instrument and survey site. The background exposure rate is then subtracted from the total to determine the net level, attributed to residual activity from licensed operations. This net level is compared with the guideline value.

$$\mu R/h = \frac{c/m}{\left[\frac{c/m}{\mu R/h}\right]^{*}} \quad or \quad \frac{c}{t \bullet \left[\frac{c/m}{\mu R/h}\right]^{*}} \tag{8-6}$$

*Site specific calibration factor for detector.

## 8.2 Measurement Uncertainty

It is recommended (EPA 1980) that each reported value include an assessment of its uncertainty. The rate of radioactive decay is not constant with time and is therefore described by a Poisson probability distribution. Based on such a distribution, the best estimate of the standard deviation (s) on a number of counts (c) is the square root of the counts, i.e.

$$s = \sqrt{c} \tag{8-7}$$

and the standard deviation in a count rate over time (t) is therefore:

$$s_r = \frac{\sqrt{c}}{t} \tag{8-8}$$

The ratio of the standard deviation to the total count (s/c) obviously decreases with the total count; in other words, the greater the number of counts recorded, the less the relative uncertainty in the measurement.

For the majority of measurements conducted during a final status survey, the number of counts due only to background will be a significant portion of the total count. The background also has an uncertainty associated with it which is taken into consideration by:

$$s_r = \sqrt{\frac{c}{t^2} + \frac{B}{t_B^2}} \tag{8-9}$$

where

$t_B$ is the time period over which the background count was determined.

The standard deviation or uncertainty in the count or count rate is converted to the same standard units used to express the measurement value, by use of the equations provided in Section 8.1. For survey and laboratory analytical data the uncertainty is usually given at the 95% confidence level which requires multiplying the standard deviation value by a factor of 1.96.

Unfortunately the uncertainty described above, commonly referred to as the "counting error," is only that due to the uncertainty in the decay process. Other sources of uncertainty will be present in the measurement and in other parameters used in the conversion calculations. Examples include the counting time, distance and area measurements, instrument efficiency, laboratory weights and physical measurements (e.g. pippetting), and chemical recovery factors. The total uncertainty associated with a particular type of measurement can be determined empirically by performing repeat (6 to 10 recommended) measurements of several selected locations and determining the average and standard deviation of the data. This will provide an estimate of the upper bound on the magnitude of systematic uncertainties. Additional guidance on identifying sources of uncertainty and estimating their magnitude is provided in (EPA 1980).

## 8.3 Minimum Detectable Activity

The concept of detection sensitivities was introduced and discussed in Section 5. For the purposes of thorough data presentation the minimum detectable activity (MDA) for each measurement procedure (and each instrument if more than one instrument is used for a given procedure) is calculated. Data from final status surveys will often be near background levels and/or below the detection sensitivity (MDA) of the procedure. Therefore negative data will be a frequent result of calculations. Use of the MDA for data that has a value less than the MDA is a common practice accepted by EPA (EPA 1989). This approach enables the surveyor to significantly reduce the number of calculations; however, use of the MDA, in place of actual data when calculating averages, will bias the results on the high side and the true conditions of the site will not be described. Substituting MDA's for actual data will also result in overestimates of source inventory and dose assessments, possibly leading to decisions for further actions that may not be justified. Finally, when evaluating data distributions, i.e. in a normalcy test, use of MDA's will result in a skewed distribution and may lead to an incorrect conclusion regarding the distribution. To avoid the pitfalls associated with use of MDA's, it is recommended that actual data be presented and used for calculational purposes. One exception to this approach might be the use of MDA's for averaging site activity levels, when the MDA is small in comparison to the applicable guideline; for the purposes of this manual, small may be considered as less than 10% of the guideline value.

## 8.4 Format for Data Presentation

All data from final status surveys should be presented in a format which provides (1) the calculated surface activity or specific radionuclide concentration value; (2) the estimated uncertainty at the 95% confidence level for that value; and (3) the estimated MDA for the measurement (EPA 1980). An example of such a format would be:

| Sample ID | Radionuclide Concentration (pCi/g) | | |
|---|---|---|---|
| | Activity | Uncertainty (95% confidence level) | MDA |
| 001 | 6.1 | 1.5 | 0.6 |
| 002 | -1.0 | 1.2 | 0.5 |
| 003 | 0.1 | 0.2 | 0.2 |

In expressing survey results, the number of significant figures is also of importance. The reason is that data should be reasonable and not mislead or imply a false level of accuracy in reported values. The appropriate number of digits in a value depends upon the magnitude of the uncertainty attached to that value. In general, final survey data, which are usually in the range of environmental data, seldom justify more than two or three significant figures for the value and one or two significant figures for the uncertainty (EPA 1980). The number of significant figures in the uncertainty is first determined and the value is stated to the last place affected by the uncertainty term. For example, if two significant figures are considered appropriate for the uncertainty, values might be reported as:

| | | |
|---|---|---|
| 93 | ± | 12 |
| 1060 | ± | 130 |
| 0.33 | ± | 0.17 |

If one significant figure is considered appropriate the same data would be reported as:

| | | |
|---|---|---|
| 90 | ± | 10 |
| 1100 | ± | 100 |
| 0.3 | ± | 0.2 |

To avoid truncation during calculations, all figures should be retained during arithmetic operations and the final results rounded to the desired number of significant figure. Rounding is done by increasing the last digit by 1, if the value to be dropped is equal to or greater than ½; if the value is less than ½, the last digit is left as is.

## 8.5 Comparison With Guideline Values

### 8.5.1 Removable Activity

Data for removable activity levels are compared directly to the guideline values. The limit for removable activity is 20% of the guideline value for total surface activity. If that level is exceeded, remediation and resurvey is necessary.

### 8.5.2 Elevated Areas of Activity

Levels of residual activity, i.e. elevated areas, which exceed the guideline value are initially compared directly with the guideline.

- Buildings or Structures

  The limit for activity on a building or structure surface is three times the guideline value, when averaged over an area of 100 $cm^2$. Residual activity exceeding this limit should be remediated and follow-up surveys performed. Areas of elevated activity between one and three times the guideline value are then tested to assure that the average surface activity level within a contiguous 1 $m^2$ area containing the elevated area is less than the guideline value.

  To evaluate whether this averaging condition is satisfied, additional measurements are performed, and the activity level and areal extent of the elevated area are determined. The average (weighted average) in the 1 $m^2$ area is then calculated, taking into consideration the relative fraction of the 1 $m^2$ occupied by the elevated area(s), using the relationship:

$$\bar{x}_w = \frac{1}{n_s} \sum_{i=1}^{n_s} x_i \left[1 - \sum_{k=1}^{n_k} A_k\right] + \sum_{k=1}^{n_k} y_k A_k \qquad (8\text{-}10)$$

where

$\bar{x}_w$ = weighted mean including elevated area(s)
$x_i$ = systematic and random measurements at point i
$n_s$ = number of systematic and random measurements
$y_k$ = elevated area activity in area k
$A_k$ = fraction of 1 $m^2$ occupied by elevated area k
$n_k$ = number of elevated areas.

Sample Calculation

The survey has identified an area of surface activity, having an average level of 7000 dpm/100 $cm^2$ and occupying an area of 800 $cm^2$. Five measurements in the contiguous 1 $m^2$, outside the elevated area, are each less than the guideline value of 5000 dpm/100 $cm^2$ and average 2300 dpm/100 $cm^2$. The weighted mean for the 1 $m^2$ area containing the elevated area is:

$$\bar{x}_w = 2300 \left[1 - \frac{800}{10000}\right] + 7000 \left[\frac{800}{10000}\right]$$

$$= 2116 + 560$$

$$= 2676 \text{ dpm/100 cm}^2$$

- soil

The limit for soil activity at any location is three times the average guideline value. Residual activity exceeding this level should be remediated and follow-up survey performed. Areas of elevated activity between one and three times the guideline value are then tested to assure that the average concentration is less than $(100/A)^{1/4}$ times the guideline value, where A is the area of the elevated activity in $m^2$. Levels exceeding this limit should be remediated. If this condition is satisfied, the average activity in the 100 $m^2$ contiguous area containing the region of elevated is then determined to assure that it is within the guideline value. Equation 8-10 is also used for this calculation, substituting 100 $m^2$ for the 1 $m^2$, used when calculating average surface activity.

Sample Calculation

Five systematic soil samples from a 100 $m^2$ grid block have the following concentrations of a specific radionuclide for which the guideline level is 10 pCi/g:

1.5 pCi/g
2.7 pCi/g
5.0 pCi/g
1.6 pCi/g
3.5 pCi/g

In addition, this area also contains a 20 $m^2$ elevated area with an average concentration of 15.5 pCi/g. Using the relationship of $(100/A)^{1/2}$ the 20 $m^2$ area would be permitted to have an average concentration of $(100/20)^{1/2}$ or 2.236 times the guideline value, i.e. 22.36 pCi/g. The activity level of 15.5 pCi/g in this elevated area satisfied this limit. The weighted average for the contiguous 100 $m^2$, containing the elevated area is:

$$\bar{x}_w = 2.9\left[1 - \frac{20}{100}\right] + 15.5\left[\frac{20}{100}\right]$$

$$= 2.32 \qquad + \qquad 3.10$$

$$= 5.42 \text{ pCi/g}$$

### 8.5.3 Exposure Rates

Exposure rate levels are compared directly with the guideline value. The maximum exposure rate may not exceed two times the guideline value, above background. If the level is above that value, the area should be remediated and resurveyed.

### 8.5.4 Calculating Average Levels

General surface activity, soil activity, and exposure rate guideline values are average values, above background, established for areas of survey unit surfaces (surface activity), 100 $m^2$ (soil activity and open land exposure rates), and 10 $m^2$ (indoor exposure rates). To enable comparison of the survey data with those guidelines, the mean ($\bar{x}$) of measurements in each of the survey units is calculated using all measurements ($n_s$) within that area:

$$\bar{x} = \frac{1}{n_s} \sum_{i=1}^{n_s} x_i \qquad (8\text{-}11)$$

### 8.5.5 Comparisons

Average levels, calculated following the procedures in Section 8.5.4, are compared with the guideline values and conditions. If the averages exceed the applicable guideline values and/or conditions, further remediation is required and follow-up measurements are performed to verify the effectiveness of the actions. After the averages satisfy the guideline values and conditions, the results are further evaluated to determine whether the data for each survey unit (i.e. group of contiguous grids or regions with the same classification of contamination potential), provides a 95% confidence level that the true mean activity level meets the guidelines.

The test is performed by calculating the average (equation 8-11) and standard deviation of the data for a particular radiological parameter in each survey unit using all measurement locations; the standard deviation is calculated by:

$$s_x = \sqrt{\frac{\sum_{i=1}^{n} (\bar{x}-x_i)^2}{n-1}} \qquad (8\text{-}12)$$

If there are areas of elevated activity in the survey unit, the weighted mean $\bar{x}_w$ (equation 8-10) for each 1 $m^2$ of building surface or 100 $m^2$ of land, containing an elevated area, is used as one of the $x_i$'s in equations 8-11 and 8-12.

The Environmental Protection Agency (EPA 1989) has recommended the following equation for testing data, relative to a guideline value, at a desired level of confidence.

Caution: Calculator doesn't feed $\bar{x}$ & $\sigma_{n-1}$ into equations

$$\mu_\alpha = \bar{x} + t_{1-\alpha,df} \frac{s_x}{\sqrt{n}} \tag{8-13}$$

where

| | |
|---|---|
| $t_{1-\alpha,\, df}$ | is the 95% confidence level obtained from Appendix B, Table B-1: df (degrees of freedom) is n-1. $\alpha$ is the false positive probability, i.e. the probability that $\mu_\alpha$ is less than the guideline value if the true mean activity level is equal to the guideline value. |
| $\bar{x}$ | is the calculated mean from equation 8-11. |
| $s_x$ | is the standard deviation from equation 8-12. |
| n | is the number of individual data points used to determine $\bar{x}$ and $s_x$. |

The value of $\mu_\alpha$ is compared to the guideline value; if $\mu_\alpha$ is less than the guideline, the area being tested meets the guideline at a 95% confidence level. This means that the probability is less than 5% that $\mu_\alpha$ will pass the test, when the true mean activity level exceeds the guideline value.

<u>Sample Calculation 1</u>

Surface activity levels (dpm/100 cm$^2$) at 35 systematic locations in an affected area are:

| | | | |
|---|---|---|---|
| 4100 | 2190 | <460 | 4000 |
| 3250 | 1430 | 1380 | <480 |
| 2120 | 4370 | 1840 | 2060 |
| 2600 | 2390 | 2160 | 1970 |
| 4750 | 3710 | 4020 | 2350 |
| 2000 | 1220 | 2030 | |
| 3140 | 1250 | 1700 | |
| 1790 | 4390 | 1510 | |
| 2000 | <460 | 2420 | |
| 3630 | 4130 | 3430 | |

Instrument background has already been subtracted for this surface activity measurement.

The mean and standard deviation are:

$\bar{x}$ = 2478 dpm/100 cm² (from equation 8-11)* Calculator
$s_x$ = 1196 dpm/100 cm² (from equation 8-12) Calculator } Same

$t_{1-\alpha,\,df}$ = 1.692 for 34 degrees of freedom (Table B-1)

$$\mu_\alpha = 2478 + 1.692 \frac{1196}{\sqrt{35}} = 2820 \text{ dpm/100 cm}^2$$

*Only minimum detectable activity (MDA) values were available for some measurement locations in this example; the MDA values were therefore used as actual activity levels for the purpose of performing this calculation.

The site-specific guideline value for the site is 5000 dpm/100 cm². Because $\mu_\alpha$ is less than 5000 dpm/100 cm², the data for this survey unit satisfy the guideline at the 95% confidence level.

Sample Calculation 2

Concentrations of net (background subtracted) activity at 20 random soil sampling locations are:

| | | | |
|---|---|---|---|
| 1.2 | pCi/g | 1.5 | pCi/g |
| 2.3 | pCi/g | 2.7 | pCi/g |
| 4.4 | pCi/g | 5.0 | pCi/g |
| 2.3 | pCi/g | 1.6 | pCi/g |
| 3.4 | pCi/g | 3.5 | pCi/g |
| 1.6 | pCi/g | 3.1 | pCi/g |
| 0.9 | pCi/g | 1.7 | pCi/g |
| 1.6 | pCi/g | 1.1 | pCi/g |
| 3.3 | pCi/g | 1.4 | pCi/g |
| 2.4 | pCi/g | 2.2 | pCi/g |

The guideline value for the site is 4 pCi/g, above background.

Although two of the samples contain activity levels above the guideline value, they satisfy the condition of the maximum concentration being less than three times the guideline value. For the purpose of this example it is assumed that the elevated areas have been tested (Section 8.5.2) and satisfy the conditions for accepting elevated areas.

The mean and standard deviation for this group of data are:

$\bar{x}$ = 2.36 pCi/g (from equation 8-11)
$s_x$ = 1.12 pCi/g (from equation 8-12)

$t_{1-\alpha,\ df}$ = 1.729 for 19 degrees of freedom (Table B-1)

$$\mu_\alpha = 2.36 + 1.729\frac{1.12}{\sqrt{20}} = 2.79 \text{ pCi/g}$$

Comparison of $\mu_\alpha$ (2.79 pCi/g) with the guideline value (4 pCi/g) indicates that the guideline has been satisfied at the desired level of confidence.

Areas for which $\mu_\alpha$ is $\leq$ the guideline values by this testing procedure are considered acceptable and no further survey actions are required. If the mean value exceeds the guideline value, the area is not acceptable and further cleanup is required. If the mean value is less than the guideline value, but the test of confidence is inconclusive, i.e. $\bar{x}$ < guideline value < $\mu_\alpha$, either (1) further cleanup with follow-up measurements/sampling or (2) additional measurements/sampling may be conducted.

The technique described above provides a conservative approach, because it gives equal weight to systematic and random measurements and to the weighted means of areas of elevated activity, which may be associated with much smaller surface areas than are the systematic and random measurements. An alternate approach to provide a less based estimate of the mean activity level is as follows.

Calculate the sample mean, $\bar{y}_k$, and sample variance, $s_{yk}^2$, for elevated level, k, of area, $A_k$.

$$\bar{y}_k = \frac{1}{n_k}\sum_{j=1}^{n_k} y_{kj} \qquad (8\text{-}14)$$

$$s_{yk}^2 = \frac{1}{n_k - 1}\sum_{j=1}^{n_k} (\bar{y}_k - y_{kj})^2 \qquad (8\text{-}15)$$

The weighted average $\overline{x_w}$ is then calculated by:

$$\overline{x_w} = \bar{x}(1-A) + \sum_{k=1}^{n_H} A_k \overline{y_k} \qquad (8\text{-}16)$$

and the estimated variance of $\overline{x_w}$ is:

$$s_w^2 = \frac{(1-A)^2 s_x^2}{n_s} + \sum_{k=1}^{n_H} \frac{A_k^2 s_{yk}^2}{n_k} \qquad (8\text{-}17)$$

The value, $\mu_\alpha$, for testing the weighted average is calculated by:

$$\mu_\alpha = \overline{x_w} + t_{1-\alpha,\, df} \bullet s_w \qquad (8\text{-}18)$$

The value of $t_{1-\alpha,\, df}$ is obtained from Appendix B, Table B-1; the degrees of freedom are determined by:

$$df = \frac{s_w^4}{D} \qquad (8\text{-}19)$$

and

$$D = \frac{(1-A)^4 s_x^4}{n_s^2 (n_s - 1)} + \sum_{k=1}^{n_H} \frac{A_k^4 s_{yk}^4}{n_k^2 (n_k - 1)} \qquad (8\text{-}20)$$

## 8.6 Identifying Additional Measurement/Sampling Needs

If $\mu_\alpha$ calculated in the previous section is greater than $C_G$ (NRC guideline value), there are two possibilities. If $\bar{x} \geq C_G$, a cleanup is required. However, if $\bar{x} < C_G$, a larger sample might be able to demonstrate compliance. The sample mean $(\bar{x})$ and standard deviation(s) for a given sample size were calculated in the previous Section using equations 8-11 and 8-12. Using these parameters, the total number of data points ($n_1$) which would be required to demonstrate that the activity level satisfies the guideline value at the desired level of confidence, is determined by:

$$n_1 = \left[\frac{s_x}{C_G - \bar{x}}\right]^2 \left[Z_{1-\alpha} + Z_{1-\beta}\right]^2 \qquad (8\text{-}21)$$

where

| | | |
|---|---|---|
| $n_1$ | = | number of data points required |
| $C_G$ | = | guideline value |
| $\bar{x}$ | = | mean |
| $s_x$ | = | sample standard deviation |
| $Z_{1-\alpha}$, $Z_{1-\beta}$ | = | standard normal variables: $\alpha$ is the false positive probability, i.e. that $\mu_\alpha < C_G$, if the true mean activity is equal to $C_G$, and $\beta$ is the false negative probability, i.e. that $\mu_\alpha > C_G$, if the true mean activity is equal to $C_G$. |

Table B-2 (Appendix B) has been provided for ease of estimating the total number of data-points required to demonstrate meeting guidelines at a false positive level of 5% and a false negative level of 10%. Subtracting the number of data points already collected (n) from this total calculated number ($n_1$), determines the number of additional measurements or samples which will be required to demonstrate the desired confidence of the data. If this calculation indicates that additional data are needed from a survey unit to demonstrate meeting the guideline, it is recommended that they be collected uniformly over the area, using the same sampling methodology as that used for the first samples. To demonstrate compliance, $\mu_\alpha$ is based on all data points; thus additional data are combined with the original data and the acceptance testing repeated. The process of determining additional samples to try to meet the guideline can only be done one time. If the additional samples do not bring $\mu_\alpha$ below the guideline, additional remediation will be required.

Sample Calculation:

Ten measurements have a mean of 7.0 pCi/g with a standard deviation of 2.8 pCi/g. The guideline value is 8.0 pCi/g.

$$\mu_{\alpha} = 7.0 + 1.833 \frac{2.8}{\sqrt{10}} = 8.6\ pCi/g$$

Although the mean is less than the guideline value, the test for significance is not satisfied at the 95% confidence level. The total number of measurements ($n_1$) required to achieve acceptance is determined from Table B-2, for the value of

$$\frac{C_G - \bar{x}}{s_x} = \frac{8.0-7.0}{2.8} = 0.36$$

$n_1$ = 68 measurements

An additional 58 (68-10) measurements are required to demonstrate acceptance.

## Determining Numbers of Background Data Points

As discussed in Section 2.3.1, the average background level determined from an initial 6-10 measurements or samples is adequate for use in evaluating radiological conditions, relative to a specific guideline value, when that average background is insignificant relative to the guideline. For the purposes of this Manual, the background has been considered insignificant if it is <10% of the guideline, although the licensee may use such background levels in determining net residual activity, following the methodology described below. When the background level is significant relative to the guideline value, i.e. >10% of the guideline, however, it is necessary that the average background determined is representative of the true background level to assure correct decisions in the final assessing site conditions. The objective for background determination is that the average level should accurately represent the true background average to within ± 20% at the 95% confidence level. Selection of this criteria for defining an acceptable accuracy for background determinations is arbitrary, based on the natural variations (of background levels) occurring in the environment and the need to keep the effort and cost devoted to background determination reasonable.

The total number of background measurements needed to satisfy the objective is calculated by:

$$n_B = \left[\frac{t_{95.5\%,df} \bullet s_x}{0.2 \bullet \bar{x}_B}\right]^2 \qquad (8\text{-}22)$$

where

| | | |
|---|---|---|
| $n_B$ | = | number of background measurements required |
| $\bar{x}_B$ | = | mean of initial background measurements |
| $s_x$ | = | standard deviation of initial background measurements |
| $t_{95.5\%, df}$ | = | t statistic for 95.5% confidence at df=n-1 degrees of freedom, where n is the number of initial background data points |

Table B-1 (Appendix B) contains a list of values for the $t_{95.5}$ statistic at various degrees of freedom. Subtracting the number of data points already collected (n) from this total calculated number ($n_B$), determines the number of additional measurements or samples which will be required to demonstrate the desired confidence of the data. If this calculation indicates that additional background data are needed, it is recommended that they be collected uniformly over the area, using the same sampling methodology as that used for the initial samples. The average background is then recalculated using all data points.

Sample Calculation:

Seven soil samples, collected for determining the background level of U-238, contained the following concentrations:

| | |
|---|---|
| 1.3 | pCi/g |
| 0.6 | pCi/g |
| 0.9 | pCi/g |
| 1.6 | pCi/g |
| 1.8 | pCi/g |
| 1.5 | pCi/g |
| 2.0 | pCi/g |

The mean (equation 8-11) and standard deviation (equation 8-12) for these data are calculated to be 1.39 pCi/g and 0.50 pCi/g, respectively; the t statistic (Table B-1, column 2) is 2.447 for 6 degrees of freedom. The total number of determinations required to establish the average background to within ± 20% of the true average at the 95% confidence level is calculated by:

$$n_1 = \left[\frac{2.447 \bullet 0.50}{0.2 \bullet 1.39}\right]^2 = 19.4$$

This calculation indicates a need for a total of 20 data points, or 13 additional (20-7) data points to satisfy the statistical objective for this case.

## 8.7 Calculating Site Inventory

The total residual activity is calculated for each radionuclide by determining the mean level for each survey unit, multiplying that average by the surface area or soil volume of the unit, and then summing all survey unit activities. The inventory will allow comparison of total residual activity at the site with established limits and devèlopment of a source term for estimating potential future impacts on public health and safety and on the environment.

Sample Calculation:

A site contains 3 interior building rooms and one land area which have been determined to have residual activity from the licensed operations. The three rooms have mean residual surface activity levels of 4100 dpm/100 $cm^2$, 2700 dpm/100 $cm^2$, and 3000 dpm/100 $cm^2$; the affected surface areas in these three rooms are 900 $m^2$, 1100 $m^2$, and 750 $m^2$, respectively.

The land area has a mean concentration of 7.3 pCi/g in the top 15 cm over 300 $m^2$ and one deeper region of residual activity occupying a volume of 10 $m^3$ and having a mean concentration of 30 pCi/g.

The total activity is calculated as follows:

Building Area 1

$$4100 dpm/100 cm^2 \bullet 900 m^2 \bullet \frac{10^4\ cm^2}{m^2} \bullet \frac{1\ pCi}{2.22\ dpm}$$

$$= 1.66 \bullet 10^8 \text{ pCi}$$

Using the same method, Building Area 2 and Building Area 3 contain total activity levels of $1.34 \bullet 10^8$ pCi and $1.01 \bullet 10^8$ pCi, respectively. Total residual activity in the three Building areas is $4.01 \bullet 10^8$ pCi.

Outside Area

Surface:

$$7.3\ pCi/g \bullet 0.15\ m \bullet 300\ m^2 \bullet 10^6 \frac{cm^3}{m^3} \bullet 1.6 \frac{g}{cm^3}$$

$= 5.26 \bullet 10^8$ pCi

Subsurface Region:

$$30\ pCi/g \bullet 10\ m^3 \bullet 10^6 \frac{cm^3}{m^3} \bullet 1.6 \frac{g}{cm^3}$$

$= 4.80 \bullet 10^8$ pCi

Total Site Inventory

| | |
|---|---|
| | $4.01 \bullet 10^8$ pCi |
| | $5.26 \bullet 10^8$ pCi |
| + | $4.80 \bullet 10^8$ pCi |
| | $14.07 \bullet 10^8$ pCi |

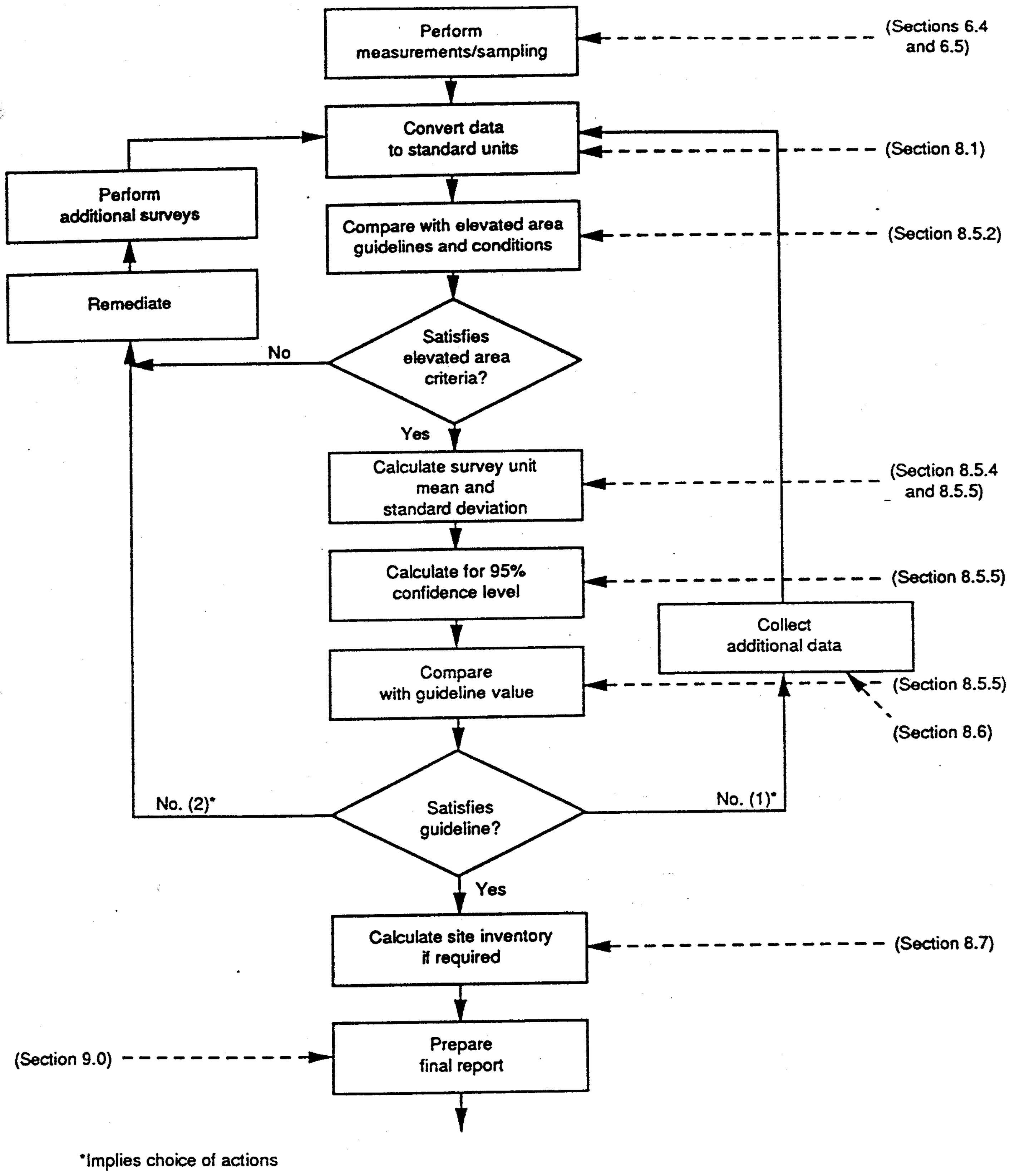


FIGURE 8-1: Flow Diagram for Interpreting and Comparing Survey Data with Guideline Value

# CHECKLIST FOR INTERPRETING SURVEY RESULTS

_____ 1. Convert survey results to same units as guidelines.

_____ 2. Compare elevated areas with guideline conditions; if conditions are not satisfied, remediate and resurvey.

_____ 3. Calculate mean and standard deviation of all measurements within survey unit.

_____ 4. Calculate the upper confidence limit ($\mu_\alpha$) for the data set.

_____ 5. Compare $\mu_\alpha$ with guideline value; if acceptance criteria is not achieved, determine number of additional measurements required.

_____ 6. Decide whether to perform additional measurements or to conduct further cleanup and follow-up surveys to demonstrate acceptance.

_____ 7. Conduct additional remediation and/or measurements; repeat checklist for new or additional data.

_____ 8. Calculate total site inventory.