

# 6 SELECTION AND APPLICATION OF AN ANALYTICAL METHOD

## 6.1 Introduction

This chapter provides guidance to both the project manager and the laboratory on the selection and application of analytical method. It offers guidance to the project manager on the development of the Analytical Protocol Specifications (APSs) from the laboratory's perspective on method appropriateness and availability. It offers guidance to the laboratory on the key elements to consider when selecting an analytical method (Chapter 1, Section 1.4.5) to meet the objectives of the APSs contained in the Statement of Work (SOW). Assuming that the laboratory has received a SOW, certain subsections of Section 6.5 provide guidance on how to review and properly evaluate the APSs therein. However, Section 6.5 also provides guidance for the project planning team on the important laboratory considerations needed to develop the Measurement Quality Objectives (MQOs). Section 6.6 deals with method validation requirements and has been written for both the project planners and the laboratory.

Because the method constitutes the major part of the analytical protocol (Chapter 1), this chapter focuses on the selection of a method. However, other parts of the protocol should be evaluated for consistency with the method (Figure 6.1). MARLAP recommends the performance-based approach for method selection. Thus, the laboratory should be able to propose whichever method meets the project's analytical data requirements (MQOs), within constraints of other factors such as regulatory requirements, cost, and project deadlines. The selection of a method by the laboratory is in response to the APSs (Chapter 3) that were formulated during the directed planning process (Chapter 2) and documented in the SOW (Chapter 5). In most project plan documents, the project manager or the project planning team has the authority and responsibility for approving the methods proposed by the laboratory. The APSs will, at a minimum, document the analytes, sample matrices, and the MQOs. A MQO is a statement of a performance objective or requirement for a particular method performance characteristic. The MQOs can be viewed as the analytical portion of the DQOs (Chapter 3).

Background material in Section 6.2.1 provides the reader with the subtleties of the performance-based approach to method selection, contrasted with the use of prescribed methods and the importance of the directed panning process and MQOs in the selection of the method. This chapter does not provide a listing of existing methods with various attributes indexed to certain applications. Analytical methods may be obtained from national standards bodies, government laboratories and publications, and the open literature.

34 In this chapter, method validation is defined as the demonstrated method applicability for a  
35 particular project. MARLAP recommends that only methods validated for a project's application  
36 be used. This recommendation should not be confused with the generic method validation that all  
37 methods should undergo during method development. The laboratory should validate the method  
38 to the APS requirements of a SOW for the analyte/matrix combination and provide the method  
39 validation documentation to the project manager prior to the implementation of routine sample  
40 processing (Section 6.6). If applicable, consideration should be given to the uncertainty of the  
41 laboratory's protocol for subsampling (heterogeneity) of the received field sample when selecting  
42 a method. Appendix F provides guidance on the minimization of subsampling uncertainty.

43 Section 6.3 provides an overview of the generic application of a method for a project and how a  
44 laboratory meets the recommendations of the guidance provided in this and other chapters.  
45 Generic considerations for the method selection process that a laboratory should evaluate are  
46 provided in Section 6.4. Project-specific considerations for method selection relevant to APSs are  
47 discussed in Section 6.5. Recommendations on the degree of method validation specified by the  
48 project planning team are outlined in Section 6.6. Sections 6.7, 6.8, and 6.9 provide guidance on  
49 analyst qualifications, method control, and continued laboratory performance assessment,  
50 respectively. Section 6.10 outlines recommendations for the method proposal and validation  
51 documentation that a laboratory should send to the project manager.

## 52 **6.2 Method Definition**

53 For this chapter, a laboratory "method" includes all physical, chemical, and radiometric processes  
54 conducted at a laboratory in order to provide an analytical result. These processes, depicted in  
55 Figure 6.1, may include sample preparation, dissolution, chemical separation, mounting for  
56 counting, nuclear instrumentation counting, and analytical calculations. This chapter will  
57 emphasize the laboratory's selection of the radioanalytical method that will be proposed in  
58 response to a SOW. Each method is assumed to address a particular analyte in a specified  
59 matrix or, in some cases, a group of analytes having the same decay emission category that can  
60 be identified through spectrometric means (e.g., gamma-ray spectrometry). However, it should be  
61 emphasized that the project planning team should have evaluated every component of the APSs  
62 for compatibility with respect to all analytes in a sample and the foreseen use of multiple  
63 analytical methods by the laboratory. For example, samples containing multiple analytes must be  
64 of sufficient size (volume or mass) to ensure proper analysis and to meet detection and quantifi-  
65 cation requirements. Multiple analytes in a sample will require multiple analyses for which a  
66 laboratory may use a sequential method that addresses multiple analytes or stand-alone individual  
67 methods for each analyte. The analytical protocol must ensure that the samples are properly

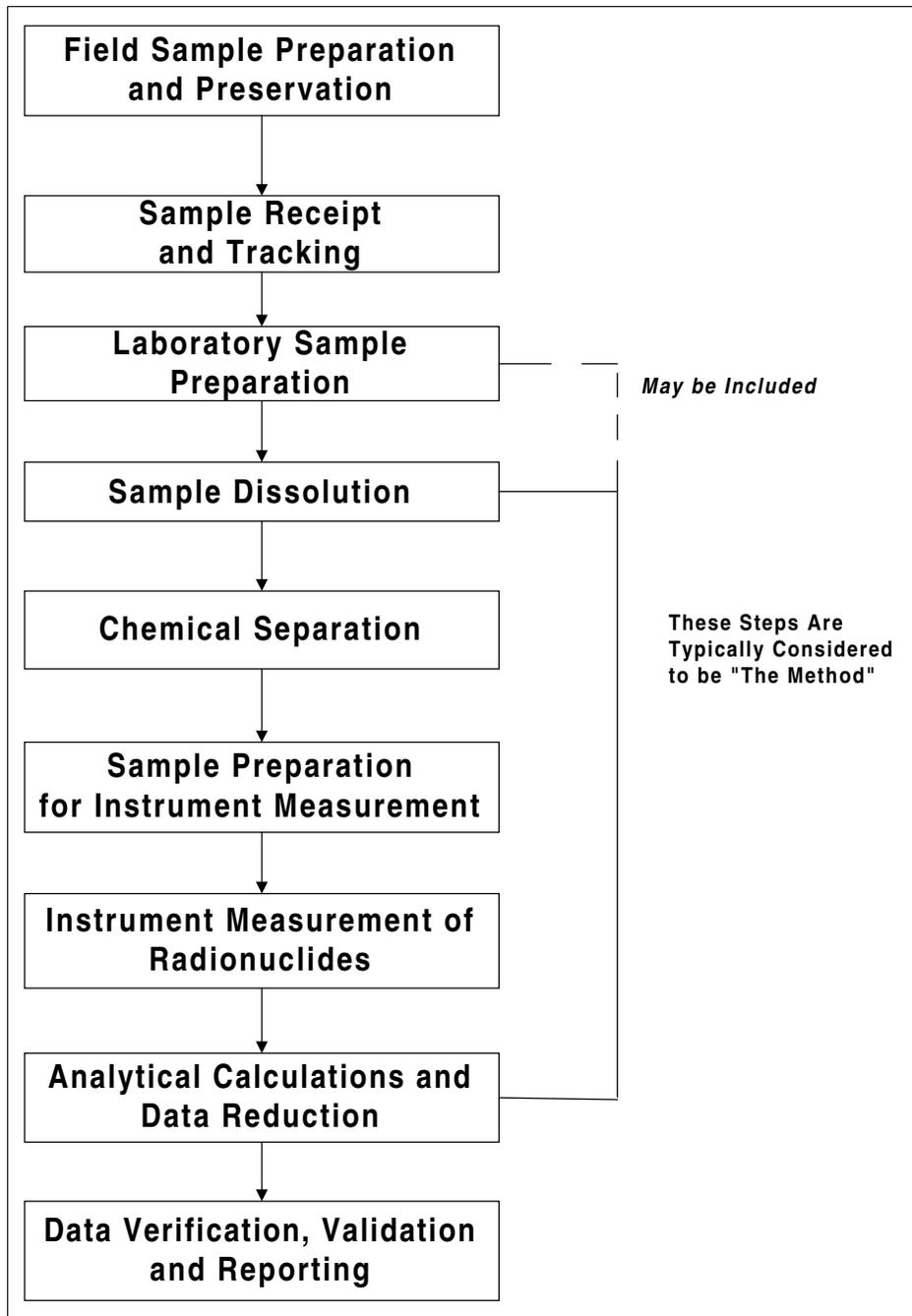


FIGURE 6.1 — Analytical process

68 preserved for each analyte and sufficient sample is collected in the field to accommodate the  
69 analytical requirements.

70 Certain aspects of a method are defined in this chapter in order to facilitate the method selection  
71 process. The following subsections describe the underlying basis of a performance-based  
72 approach to method selection and provide a functional definition related to MARLAP.

73 *Performance-Based Approach and Prescriptive Method Application*

74 MARLAP uses a performance-based approach to select a method, which is based on a  
75 demonstrated capability to meet defined project performance criteria (e.g., MQOs). With a  
76 properly implemented quality system, a validated method should produce appropriate and  
77 technically defensible results under the applicable conditions. The selection of any new method  
78 usually requires additional planning and, in some cases, may result in additional method  
79 development or validation. The selection of a method under the performance-based approach  
80 involves numerous technical, operational, quality, and economic considerations. However, the  
81 most important consideration in the selection of a method under the performance-based approach  
82 is compliance with the required MQOs for the analytical data. These requirements should be  
83 defined in the SOW or appropriate project plan document.

84 When developing the MQOs, the project planning team should have evaluated all processes that  
85 have a potential to affect the analytical data. Those involved in the directed planning process  
86 should understand and communicate the needs of the project. They should also understand how  
87 the sampling (field, process, system, etc.) and analytical activities will interact and the ramifica-  
88 tions that the data may have on the decisionmaking process. These interactive analysis and  
89 communication techniques should be applied in all areas where analytical data are produced. As  
90 new projects are implemented, it should not be assumed that the current methods are necessarily  
91 the most appropriate and accurate; they should be reevaluated based on project objectives. The  
92 application of a performance-based approach to method selection requires the quantitative  
93 evaluation of all aspects of the analytical process. Once the MQOs for a project have been  
94 determined and incorporated into the APSs, under the performance-based approach, the  
95 laboratory will evaluate its existing methods and propose one or more methods that meet each  
96 APS. This chapter contains guidance on how to use the APSs in the laboratory's method  
97 evaluation process.

98 The objective of a performance-based approach to method selection is to facilitate the selection,  
99 modification, or development of a method that will reliably produce quality analytical data as  
100 defined by the MQOs. Under the performance-based approach, a laboratory, responding to a

101 SOW, will propose a method that best satisfies the requirements of the MQO and the laboratory's  
102 operations.

103 In certain instances, the requirement to use prescribed methods may be included in the SOW. The  
104 term "prescribed methods" has been associated with those methods that have been selected by  
105 industry for internal use or selected by a regulatory agency, such as the U.S. Environmental  
106 Protection Agency (EPA), for specific programs. The methods for analyzing radionuclides in  
107 drinking water prescribed by EPA (1980 ) provides an example of applying a limited number of  
108 methods to a well-defined matrix. In many companies or organizations, prescribed methods are  
109 widely used. Methods that have been validated for a specific application by national standard  
110 setting organizations such as the American Society for Testing and Materials (ASTM), American  
111 National Standards Institute (ANSI), American Public Health Association (APHA), etc., may  
112 also be used as prescribed methods by industry and government agencies.

113 Typically, the prescribed methods were selected by an organization to meet specific objectives  
114 for a regulation under consideration or for a program need. In most cases, the prescribed methods  
115 had undergone some degree of method validation, and the responsible organization had required  
116 a quality system to demonstrate continued applicability and quality, as well as laboratory  
117 proficiency. The use of any analytical method, whether prescribed or from the performance-based  
118 approach, has a life cycle that can be organized into the major categories of selection, validation,  
119 and continued demonstrated capability and applicability. This chapter will cover in detail only  
120 the first two of these categories. A discussion on ongoing laboratory evaluations is presented in  
121 Chapter 7 and Appendix C.

122 A final note should be made relative to prescribed methods and the performance-based approach  
123 to method selection. The performance-based approach for method selection allows more latitude  
124 in dealing with the potential diversity of matrices (such as waste-, sea-, ground- or surface water;  
125 biota; air filters; waste streams; swipes; soil; sediment; or sludge) from a variety of projects, or in  
126 dealing with different levels of data quality requirements or a laboratory's analytical proficiency.  
127 Even though the prescribed method approach may initially appear suitable and cost effective, it  
128 does not allow a laboratory to select a method from the many possible methods that will meet the  
129 MQOs.

130 Many individuals have the wrong impression that prescribed methods do not need to be validated  
131 by a laboratory. However, as discussed in this chapter, all methods should be validated to some  
132 level of performance for a particular project by the laboratory prior to their use. In addition, the  
133 laboratory should demonstrate continued proficiency in using the method through internal QC  
134 and external performance evaluation (PE) programs (Chapter 18).

135 **6.3 Life Cycle of Method Application**

136 In responding to a SOW for a given analyte/matrix combination, a laboratory may have one or  
 137 more methods that may be appropriate for meeting the MQOs. The final method selected from a  
 138 set of methods may be influenced by many other technical, operational, or quality considerations.  
 139 Figure 6.2 provides an overview of the life cycle of the method application. Figure 6.3 expands  
 140 the life cycle into a series of flow diagrams.

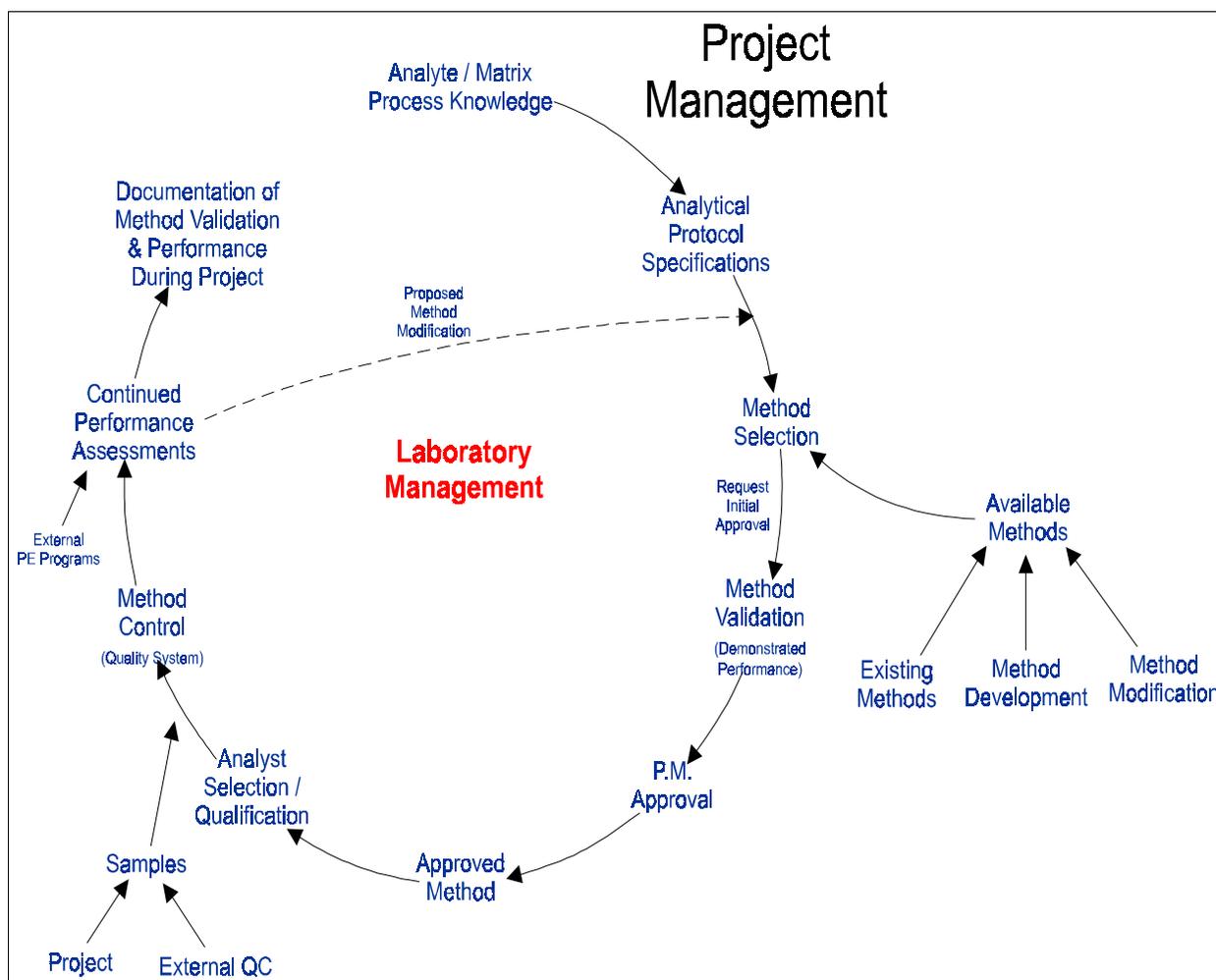
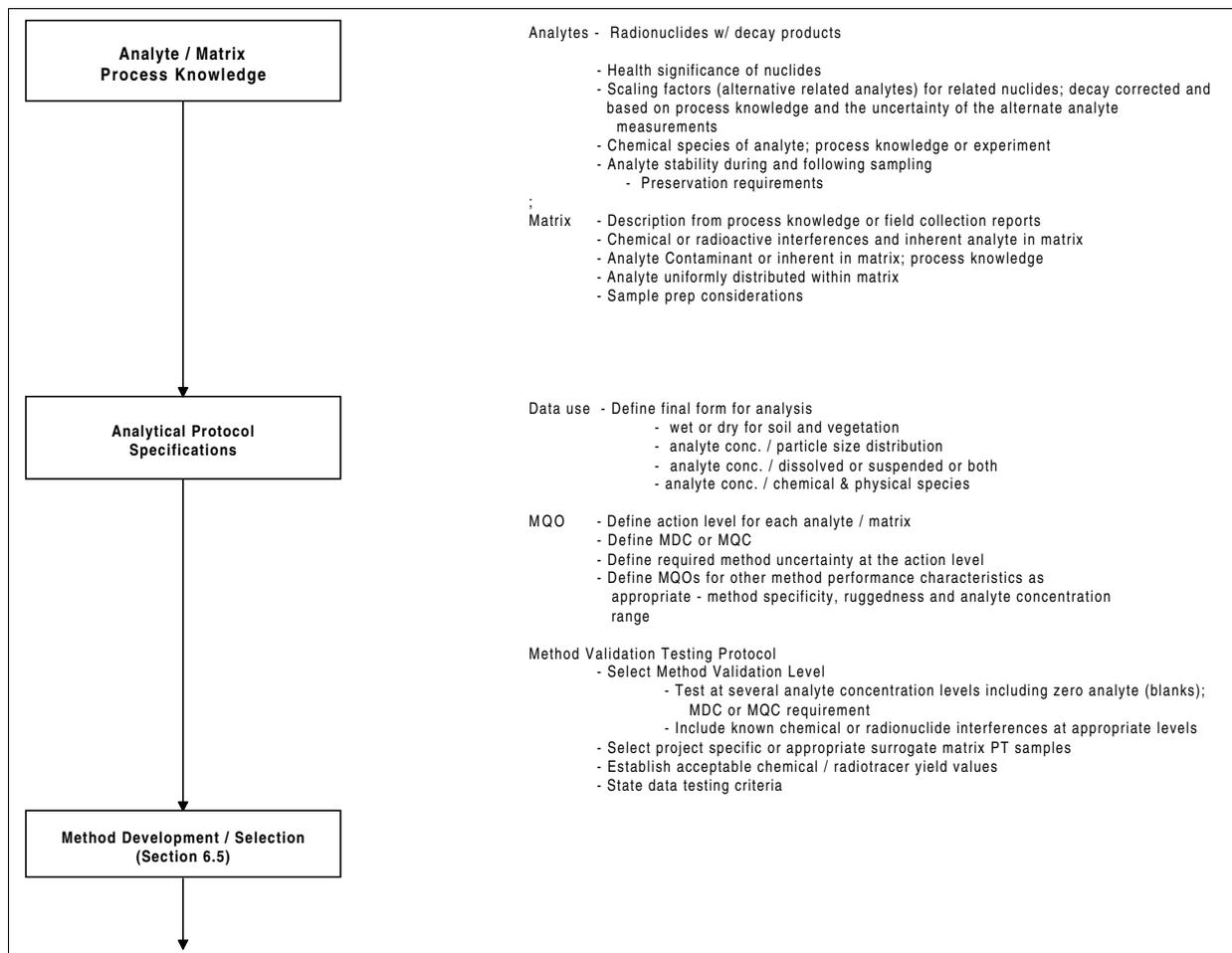
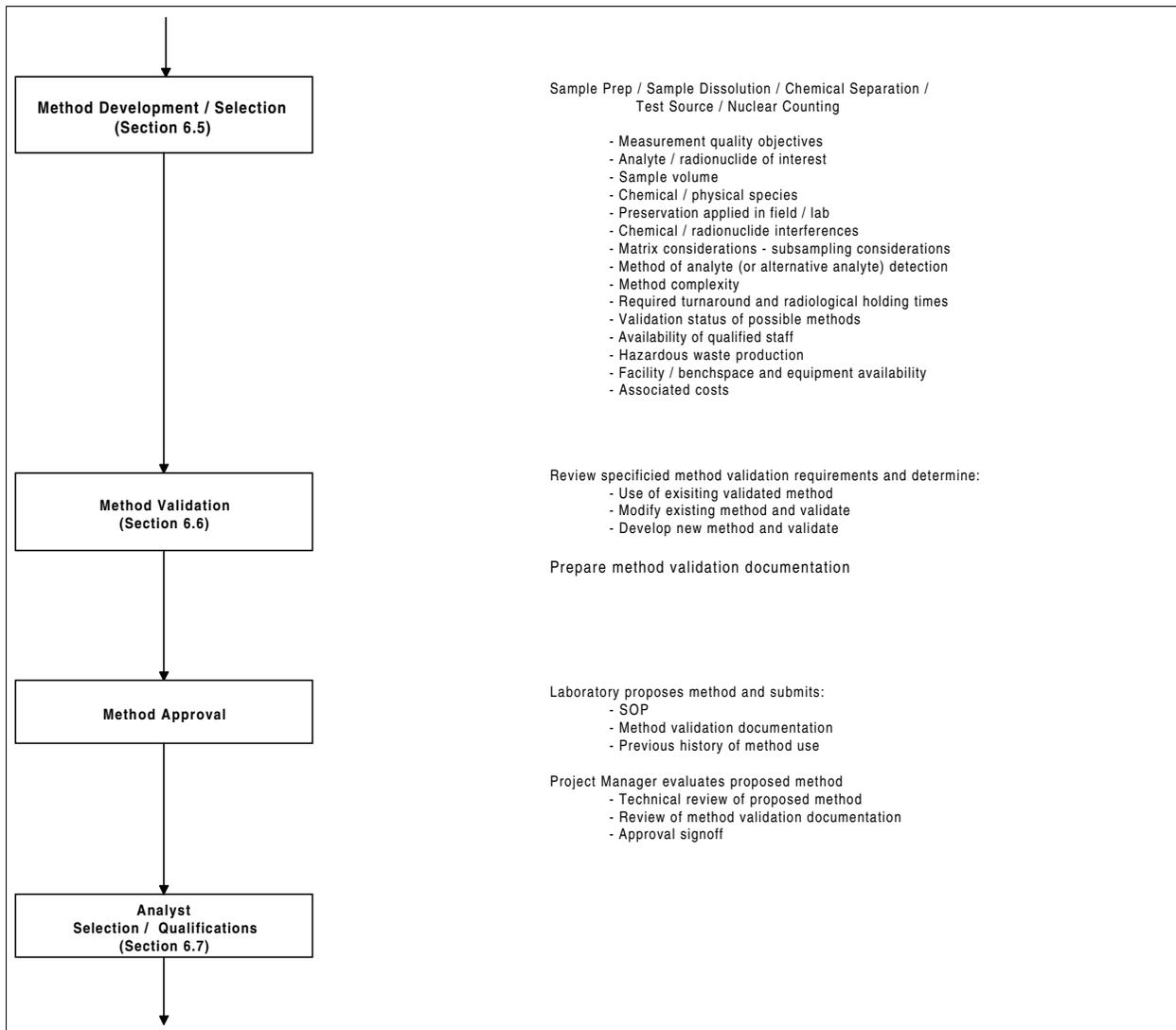


FIGURE 6.2 — Method application life cycle

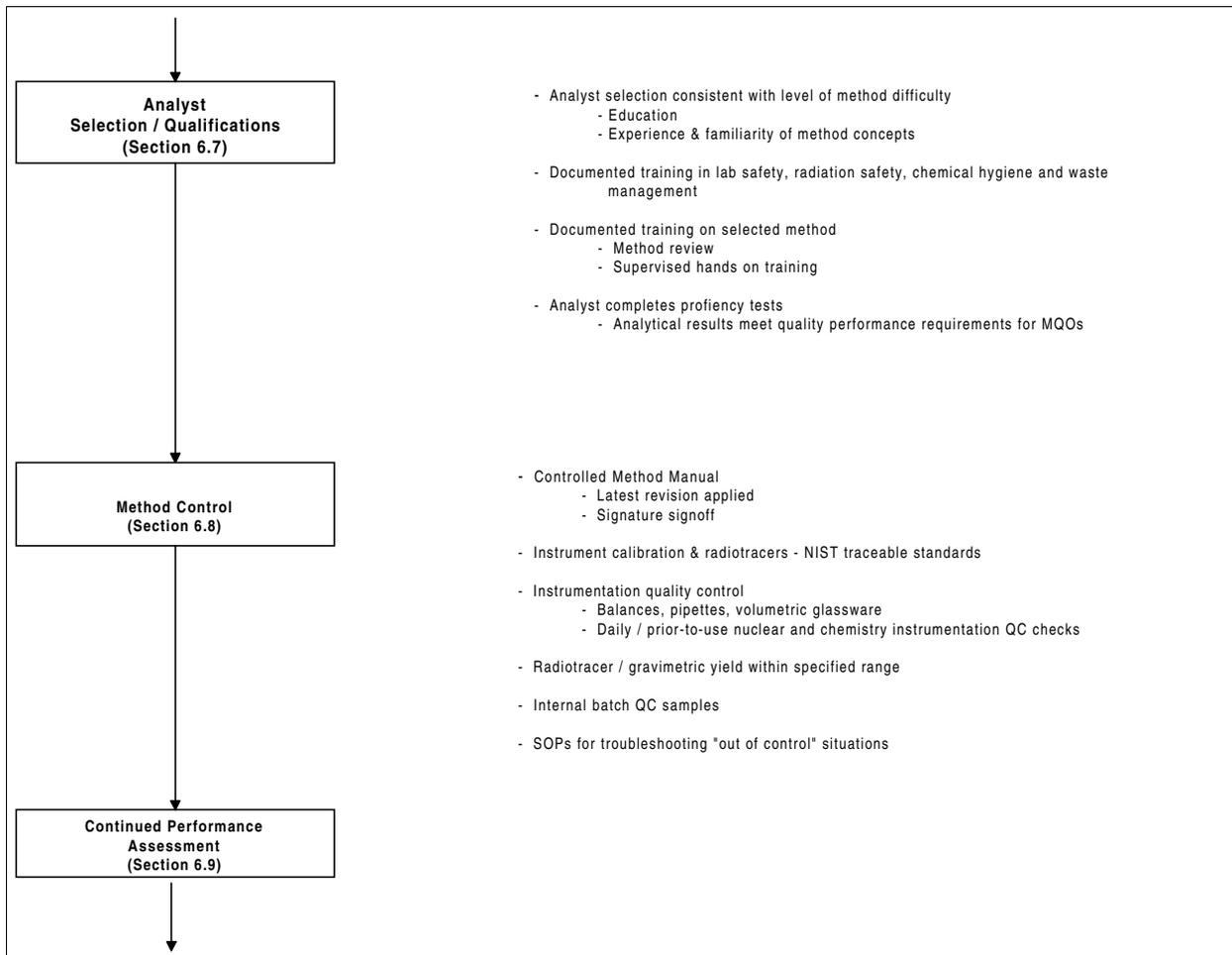


**FIGURE 6.3 — Expanded Figure 6.2 addressing the laboratory’s method evaluation process**

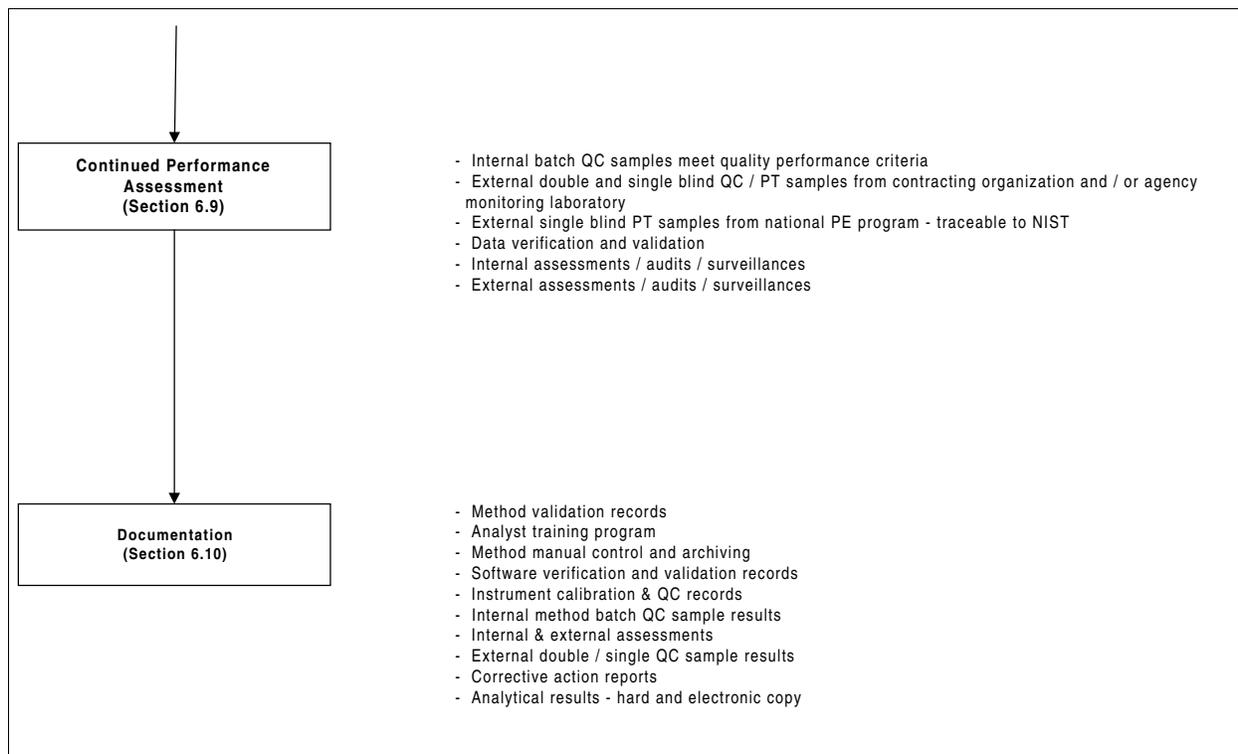
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**FIGURE 6.3 (continued) — Expanded Figure 6.2 addressing the laboratory’s method evaluation process**



**FIGURE 6.3 (continued) — Expanded Figure 6.2 addressing the laboratory's method evaluation process**



**FIGURE 6.3 (continued) — Expanded Figure 6.2 addressing the laboratory’s method evaluation process**

141 **6.4 Generic Considerations for Method Development and Selection**

142 This section provides guidance on the technical, quality, and operational considerations for the  
143 development of a new method or the selection of an existing radioanalytical method. Unless  
144 required by a regulatory or internal policy, rarely should a method be specified in an APS or a  
145 SOW. MARLAP recommends that a SOW containing the MQOs and analytical process  
146 requirements be provided to the laboratory.

147 If the nature of the samples and analytes are known in advance, and variations in a sample matrix  
148 and analyte concentration are within a relatively small range, the development or selection of  
149 analytical methods is easier. In most situations, however, the number of samples, sample  
150 matrices, analyte interferences, chemical form of analytes, and variations among and within  
151 samples may influence the selection of a method for a given analyte. A number of radioanalytical  
152 methods are available, but no single method provides a general solution (all have advantages and

153 disadvantages). The method selection process should consider not only the classical  
154 radiochemical methods involving decay emission detection (alpha, beta or gamma) but also non-  
155 nuclear methods, such as mass spectrometric and kinetic phosphorescence analysis.

156 In the performance-based approach to method selection, the laboratory may select and propose a  
157 gross measurement (alpha, beta, or gamma) method that can be applied to analyte concentrations  
158 well below the action level for the analyte, as well as an analyte specific method for analyte  
159 levels exceeding a proposed “screening level” that is a fraction of the action level. For example,  
160 it may be acceptable to propose a gross measurement method when its combined standard  
161 uncertainty meets the method uncertainty requirement at concentration levels much below the  
162 action level. A gross measurement method may be employed initially for some projects. Such an  
163 approach would have to be agreed to by the laboratory and project manager. The method  
164 validation, discussed in Section 6.6, should demonstrate that the gross measurement method can  
165 measure the analyte of interest (directly or indirectly) at the proposed analyte concentration and  
166 meet the uncertainty requirement in the presence of other radionuclides. Appendix C provides  
167 guidance on how to determine the acceptable method uncertainty at an analyte concentration  
168 relative to the action level.

169 In general, the development or selection of a method follows several broad considerations. These  
170 include analyte and matrix characteristics, technical complexity and practicality of methods,  
171 quality requirements, availability of equipment, facility and staff resources, regulatory concerns,  
172 and economic considerations. Each of the broad considerations can be detailed. The following  
173 list, although not inclusive, provides insight into the selection of an appropriate method. Many of  
174 these categories are discussed in subsequent MARLAP Part II chapters.

- 175     ◇ Analyte/radionuclide/isotope of interest
  - 176         ○ Decay emission (particle or photon), atom detection, or chemical (photon detection)
  - 177         ○ Half-life of analyte
  - 178         ○ Decay products (progeny); principal detection method or interference
  - 179         ○ Chemical/physical forms (e.g., gas, volatile)
  - 180         ○ Use of nondestructive or destructive sample analysis
  
- 181     ◇ Level of other radionuclides or chemical interference
  - 182         ○ Level of decontamination or selectivity required, e.g., a decontamination factor of  $10^3$  for
  - 183             an interfering nuclide ( $^{60}\text{Co}$ ) present with the analyte of interest ( $^{241}\text{Pu}$ )
  - 184         ○ Resolution of measurement technique
  - 185         ○ Robustness of technique for handling large fluctuations in interference levels and
  - 186             variations in a matrix

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- 187       ○ Radionuclides inherent in background
- 188   ◇ Matrix
- 189       ○ Destructive testing
- 190       – Stable elemental interferences
- 191       – Difficulty in dissolution of a matrix
- 192       – Difficulty in ensuring homogeneity of aliquant
- 193       – Inconsistency in chemical forms and oxidation states of the analyte versus the tracer
- 194       ○ Non-destructive testing
- 195       – Heterogeneity of final sample for analysis
- 196       – Self absorption of particle/photon emissions within a matrix
  
- 197   ◇ Degree of method complexity
- 198       ○ Level of technical ability required of analysts
- 199       ○ Reproducibility of quality results between analysts
- 200       ○ Method applicability to sample batch processing
- 201       ○ Extensive front-end chemical-processing technique (sample dissolution, analyte
- 202       concentration and purification/isolation, preparation for final form for radiometrics)
- 203       ○ Nuclear instrumentation oriented technique (minimal chemical processing)
  
- 204   ◇ Required sample turnaround time
- 205       ○ Half-life of analyte
- 206       ○ Sample preparation or chemical method processing time
- 207       ○ Nuclear instrumentation measurement/analysis time
- 208       ○ Chemical or sample matrix preservation time
- 209       ○ Batch processing
- 210       ○ Degree of automation available/possible
  
- 211   ◇ Status of possible methods and applications
- 212       ○ Validated for the intended application
- 213       ○ Staff qualified and trained to use method(s)
- 214       ○ Existing QC program for method(s)
- 215       ○ Specialized equipment, tracers, reagents, or materials available
  
- 216   ◇ Hazardous or Mixed waste production
- 217       ○ Older classical techniques versus new advanced chemical technologies
- 218       ○ Availability and expense of waste disposal
  
- 219   ◇ Associated costs

- 220 ○ Labor, instrumentation usage, facilities, radiological waste costs
- 221 ○ Method applicability to portable or mobile laboratory facilities
- 222 ○ Availability of service hookups
- 223 ○ Need for facility environmental controls
- 224 ○ Need for regulatory permitting of mobile laboratory facility

## 225 **6.5 Project-Specific Consideration for Method Selection**

226 Certain parameters of the APSs (See Chapter 3 and the example in Figure 3.2) within the SOW  
227 are important to the method selection process. These include the analytes, matrix type, matrix  
228 characterization, analyte and matrix interferences, analyte speciation information gathered from  
229 process knowledge, sample process specifications (such as radiological holding times and sample  
230 processing turnaround times), and the MQOs. While these issues should be resolved during  
231 project planning, they are presented here as guidance to the laboratory for their review and  
232 evaluation of the technical adequacy of the SOW and to provide context for the method  
233 evaluation and selection process. Many of the issues from the project planning point of view are  
234 discussed in Section 3.3.

### 235 **6.5.1 Matrix and Analyte Identification**

236 The first step in selecting a method is knowing what analytes and sample matrices are involved.  
237 The following sections discuss what important information should accompany analyte and matrix  
238 identification.

#### 239 **6.5.1.1 Matrices**

240 A detailed identification and description of the sample matrix are important aspects in the  
241 selection of an analytical method to meet the MQOs. The SOW should provide the necessary  
242 detailed sample matrix description, including those important matrix characteristics gathered  
243 from process knowledge. The laboratory should evaluate whether the existing sample preparation  
244 and dissolution steps of a method (Chapters 10 and 12 through 15) will be sufficient to meet the  
245 MQOs or the method validation requirements. The matrix will also determine, to a certain extent,  
246 waste handling and disposal at the laboratory. If the matrix description is too vague or generic,  
247 the laboratory should contact the technical representative named in the SOW and request  
248 additional information.

249  
250 The laboratory should ensure that the sample matrix description in the SOW reflects what is  
251 considered to be the “sample” by the project manager and the description is of sufficient detail to

252 select the method preparation or analyte isolation steps that will meet the MQOs for the matrix.  
253 The laboratory should not accept generic sample matrix descriptions such as liquids or solids. For  
254 example, the differences between potable water and motor oil are obvious, but both may be  
255 described as a “liquid sample.” However, there may be only subtle differences between potable  
256 surface water and groundwater but major differences between potable and process effluent  
257 waters. The laboratory should consider how much method robustness is needed in order to  
258 address the varied amounts of possible stable elements or compounds within a non-specified  
259 water matrix. Furthermore, when water from a standing pool is received in the laboratory, it may  
260 contain some insoluble matter. Now the questions arise whether the sample is the entire contents  
261 of the container, what remains in the container, the insoluble material, or just the water? A clay  
262 will act as an ion exchange substrate, while a sand may have entirely different retention  
263 properties. Both can be described as a soil or sediment, but the properties with which they retain  
264 a radionuclide are substantially different; thus, the method to properly isolate a particular  
265 radionuclide will vary. The laboratory should ensure that the selected method is consistent with  
266 the intended sample matrix, and the analytical results convey analyte concentration related to the  
267 proper matrix (i.e., Bq/L dissolved, Bq/L suspended, or Bq/L total). For such cases, the  
268 laboratory should request the project manager to clarify the “matrix” or “sample” definition.

269 Matrices generically identified as “solid” require additional clarification or information in order  
270 to select and validate a method properly. For example, sludges from a sewerage treatment facility  
271 may be classified as a solid, but the suspended and aqueous portions (and possibly the dried  
272 residual material) of the sample may have to be analyzed. Normally, the radioanalyte concentra-  
273 tion in soils and sediments is reported in terms of becquerels per dry weight. However, certain  
274 projects may require additional sample process specifications (Section 6.5.4) related to the soil or  
275 sediment matrix identification that will affect the method selection process and the reporting of  
276 the data. This may involve sectioning of core samples, specified drying temperature of the  
277 sample, determining wet-to-dry weight ratio, removing organic material or detritus, homogeni-  
278 zing and pulverizing, sieving and sizing samples, etc. In order to determine the average analyte  
279 concentration of a sample of a given size containing radioactive particles, proper sample  
280 preparation and subsampling coupled with the applicable analytical methods are required  
281 (Chapter 12 and Appendix F). For alpha-emitting radionuclides, the method selected may only be  
282 suitable to analyze a few grams of soil or sediment, depending on the organic content. The  
283 laboratory should identify to the project manager the typical subsample or aliquant size that is  
284 used for the proposed method. If information provided to the laboratory on process knowledge  
285 indicates that there may be a possibility of radioactive particles, or selected analyte adsorption  
286 onto soil or sediment particles, the laboratory should propose sample preparation and analytical  
287 methods that will address these matrix characteristics. The laboratory should submit the proposed  
288 methods annotated with the suspected matrix characterization issues.

289 When selecting the methods for the analysis of flora (terrestrial vegetation, vegetables, aquatic  
290 plants, algae, etc.) or fauna (terrestrial or aquatic animals) samples, the detailed information on  
291 the matrix or the unique process specifications should be used by the laboratory to select or  
292 validate the method, or both. The laboratory should ensure that the specific units for the  
293 analytical results are consistent with the matrix identification and unique process specifications  
294 stated in the SOW. Most flora and fauna results are typically reported in concentrations of wet  
295 weight. However, for dosimetric pathway analyses, some projects may want only the edible  
296 portion of the sample processed and the results to reflect this portion, e.g., fillet of sport fish,  
297 meat and fluid of clams, etc. For the alpha- and beta-emitting radionuclides, aquatic vegetation  
298 normally is analyzed in the dry form, but the analyte concentration is reported as wet weight. The  
299 laboratory should ensure that the sample preparation method (Chapter 12) includes the  
300 determination of the necessary wet and dry weights.

301 These considerations bear not only on the method selected but also on how the sample should be  
302 collected and preserved during shipment. When possible, the laboratory should evaluate the  
303 proposed sample collection and preservation methods, as well as timeliness of shipping, for  
304 consistency with the available analytical methods. Discrepancies noted in the SOW for such  
305 collateral areas should be brought to the attention of the project manager. For example, sediment  
306 samples that have been cored to evaluate the radionuclide depth profile should have been  
307 collected and treated in a fashion to retain the depth profile. A common method is to freeze the  
308 core samples in the original plastic coring sleeves and ship the samples on ice. The SOW should  
309 define the specifics on how to treat the core samples and the method of sectioning the samples  
310 (e.g., cutting the cores into the desired lengths or flash heating the sleeves with subsequent  
311 sectioning).

312 The SOW should have properly delineated the proper matrix specifications required for method  
313 validation. In some cases, sufficient information may have been provided to define the  
314 parameters necessary to prepare method validation reference material (MVRM) for method  
315 validation purposes (Section 6.6). The laboratory should ensure that sufficient information and  
316 clarity have been provided on the matrix to conduct a proper method validation.

#### 317 6.5.1.2. Analytes and Potential Interferences

318 The SOW should describe the analytes of interest and the presence of any other chemical and  
319 radionuclide contaminants (potential method interferences and their anticipated concentration)  
320 that may be in the samples. This information should be provided in the SOW to allow the  
321 laboratory's radiochemist to determine the specificity and robustness of a method that will  
322 address the multiple analytes and their interferences. The delineation of other possible interfering

323 radionuclides is extremely important in the selection of a method to ensure that the necessary  
324 decontamination factors and purification steps are considered.

325 The size of the sample needed by the laboratory will depend on the number of analytes and  
326 whether the laboratory will select individual methods for each analyte or a possible “sequential”  
327 analytical method, where several analytes can be isolated from the same sample and analyzed. If  
328 a sample size is listed in the SOW, the laboratory should determine if there will be sufficient  
329 sample available to analyze all analytes, the associated QC samples, and any backup sample for  
330 re-analyses. Other aspects, such as the presence of short-lived analytes or analytes requiring very  
331 low detection limits, may complicate the determination of a proper sample size.

332 The laboratory should ensure that the method validation requirements in the SOW are consistent  
333 with the analytes and matrix. The method validation protocols defined in Section 6.6 are  
334 applicable to methods for single analyte analyses or to a “sequential method” where several  
335 analytes are isolated and analyzed. The laboratory should develop a well-planned protocol  
336 (Section 6.6.2) for method validation that considers the method(s), analyte(s), matrix and  
337 validation criteria.

### 338 **6.5.2 Process Knowledge**

339 Process knowledge typically is related to facility effluent and environmental surveillance  
340 programs, facility decommissioning, and site remediation activities. Important process  
341 knowledge may be found in operational history or regulatory reports associated with these  
342 functions or activities. It is imperative that the laboratory review the information provided in the  
343 SOW to determine whether the anticipated analyte concentration and matrix are consistent with  
344 the scope of the laboratory operations. Process knowledge contained in the SOW should provide  
345 sufficient detail for the laboratory to determine, quickly and decisively, whether or not to pursue  
346 the work. If sufficient detail is not provided in the SOW, the laboratory should request the project  
347 planning documents. Laboratories having specialized sample preparation facilities that screen the  
348 samples upon arrival can make the necessary aliquanting or dilutions to permit the processing of  
349 all low-level samples in the laboratories. Laboratories that have targeted certain sectors of the  
350 nuclear industry or a particular nuclear facility may be very knowledgeable in the typical  
351 chemical and physical forms of the analytes of a given sample matrix and may not require  
352 detailed process knowledge information. However, under these circumstances, the laboratory’s  
353 method should be robust and rugged enough to handle the expected range of analyte concen-  
354 trations, ratios of radionuclide and chemical interferences, and variations in the sample matrix.

355 Process knowledge may provide valuable information on the possible major matrix constituents,  
356 including major analytes, chemical/physical composition, hazardous components, radiation  
357 levels, and biological growth (e.g., bacteria, algae, plankton, etc.) activities. When provided, the  
358 laboratory should use this information to determine if the sample collection and preservation  
359 methodologies are consistent with the proposed radioanalytical method chosen. In addition, the  
360 information also should be reviewed to ensure that the proposed sample transportation or  
361 shipping protocols comply with regulations governing the laboratory operation.

362 Process knowledge information in the SOW may be used by the laboratory to refine method  
363 selection from possible radiometric/chemical interferences, chemical properties of the analytes or  
364 matrix, and hazardous components, among others. Chapter 14 describes the various generic  
365 chemical processes that may be used to ensure proper decontamination or isolation of the analyte  
366 from other interferences in the sample. These include ion exchange, co-precipitation, oxidation/  
367 reduction, and solvent extraction among others. The process knowledge information provided in  
368 the SOW should be reviewed to determine whether substantial amounts of a radionuclide that  
369 normally would be used as a radiotracer will be present in the sample. Similarly, information on  
370 the levels of any stable isotope of the analyte being evaluated is equally important. Substantial  
371 ambient or background amounts of either a stable isotope of the radionuclide or the radiotracer in  
372 the sample may produce elevated and false chemical yield factors. In addition, substantial  
373 amounts of a stable isotope of the analyte being evaluated may render certain purification  
374 techniques inadequate (e.g., ion exchange or solid extractants).

### 375 **6.5.3 Radiological Holding and Turnaround Times**

376 The SOW should contain the requirements for the analyte's radiological holding and sample  
377 turnaround times. MARLAP defines radiological holding time as the time differential between  
378 the date of sample collection and the date of analysis. It is important that the laboratory review  
379 the specifications for radionuclides that have short half-lives (less than 30 days), because the  
380 method proposed by the laboratory may depend on the required radiological holding time. For  
381 very short-lived radionuclides, such as <sup>131</sup>I or <sup>224</sup>Ra, it is very important to analyze the samples  
382 within the first two half-lives in order to meet the MQOs conveniently. A laboratory may have  
383 several methods for the analysis of an analyte, each having a different analyte detection and  
384 quantification capability. Of the possible methods available, the method selected and proposed by  
385 the laboratory most likely will be dependent on the radiological holding time requirement, half-  
386 life of the analyte, and the time available after sample receipt at the laboratory. When a  
387 laboratory has several methods to address variations in these constraints, it is recommended that  
388 the laboratory propose more than one method with a clarification that addresses the radiological  
389 holding time and MQOs. In some cases, circumstances arise which require the classification of

390 sample processing into several time-related categories (Chapter 5). For example, the determina-  
391 tion of  $^{131}\text{I}$  in water can be achieved readily within a reasonable counting time through direct  
392 gamma-ray spectrometry (no chemistry) using a Marinelli beaker counting geometry, when the  
393 detection requirement is 0.4 Bq/L and the radiological holding time is short. However, when the  
394 anticipated radiological holding time is in the order of weeks, then a radiochemistry method  
395 using beta detection or beta-gamma coincidence counting would be more appropriate to meet the  
396 detection requirement. The more sensitive method also may be used when there is insufficient  
397 sample size or when the analyte has decayed to the point where the less sensitive method cannot  
398 meet the required MQOs. Another example would be the analysis of  $^{226}\text{Ra}$  in soil, where the  
399 laboratory could determine the  $^{226}\text{Ra}$  soil concentration through the quantification of a  $^{226}\text{Ra}$   
400 decay product by gamma-ray spectrometry after a certain ingrowth period, instead of direct  
401 counting of the alpha particle originating from the final radiochemical product (micro-  
402 precipitate) using alpha spectrometry.

403 Sample (processing) turnaround time normally means the time differential from the receipt of the  
404 sample at the laboratory to the reporting of the analytical results. As such, the laboratory should  
405 evaluate the SOW to ensure that the sample turnaround time, radiological holding time, data  
406 reduction and reporting times, and project needs for rapid data evaluation are consistent and  
407 reasonable. Method selection should take into consideration the time-related SOW requirements  
408 and operational aspects. When discrepancies are found in the SOW, the laboratory should  
409 communicate with the project manager and resolve any issue. Additionally, the response to the  
410 SOW should include any clarifications needed for sample turnaround time and/or radiological  
411 holding time issues.

#### 412 **6.5.4 Unique Process Specifications**

413 Some projects may incorporate detailed sample processing parameters, specifications, or both  
414 within the SOW. Specifications for parameters related to sample preparation may include the  
415 degree of radionuclide heterogeneity in the final sample matrix prepared at the laboratory, the  
416 length of the sections of a soil or sediment core for processing, analysis of dry versus wet weight  
417 material, partitioning of meat and fluid of bivalves for analyses, and reporting of results for  
418 certain media as a dry or wet weight. Specifications related to method analysis could include  
419 radionuclide chemical speciation in the sample matrix. The laboratory must evaluate these  
420 specifications carefully, since various parameters may affect the method proposed by the  
421 laboratory. When necessary, the laboratory should request clarification of the specifications in  
422 order to determine a compatible method. In addition, the laboratory should ensure that the  
423 method validation process is consistent with the unique process requirements. In some cases, not  
424 all special process specifications must be validated and, in other cases, site-specific materials

425 (also referred to as MVRM) will be required for method validation. When necessary, the  
426 laboratory also should request site-specific reference materials having the matrix characteristics  
427 needed for proper method validation consistent with the special process requirements. It is  
428 incumbent upon the laboratory to understand clearly the intent of the special process  
429 specifications and how they will be addressed.

### 430 **6.5.5 Measurement Quality Objectives**

431 The specific method performance characteristics having a measurement quality objective may  
432 include:

- 433 • Method uncertainty at a specified analyte concentration level;
- 434 • Quantification capability (minimum quantifiable concentration);
- 435 • Detection capability (minimum detectable concentration);
- 436 • Applicable analyte concentration range;
- 437 • Method specificity; and
- 438 • Method ruggedness.

439 How each of these characteristics affect the method selection process will be discussed in detail  
440 in the subsequent paragraphs.

#### 441 6.5.5.1 Method Uncertainty

442 From the directed planning process, the required method uncertainty at a stated analyte  
443 concentration should have been determined for each analyte/matrix combination. The method  
444 uncertainty requirement may be linked to the width of the gray region (Appendix C). MARLAP  
445 recommends that the SOW include the specifications for the action level and the required method  
446 uncertainty for the analyte concentration at the action level for each analyte/matrix. For research  
447 and baseline monitoring programs, the action level and gray region concepts may not be  
448 applicable. However, for these applications, the project manager should establish a concentration  
449 level of interest and a required method uncertainty at that level. The laboratory should ensure that  
450 this method uncertainty requirement is clearly stated in the SOW.

451 The laboratory should select a method that will satisfy the method uncertainty requirement at the  
452 action level or other required analyte level. MARLAP uses the term “method uncertainty” to  
453 refer to the predicted uncertainty of a result that would be measured if a method were applied to a  
454 hypothetical laboratory sample with a specified analyte concentration. The uncertainty of each  
455 input quantity (method parameter) that may contribute significantly to the total uncertainty

456 should be evaluated. For some methods, the uncertainty of an input quantity may vary by analyst  
457 or spectral unfolding software. Chapter 19 provides guidance on how to calculate the combined  
458 standard uncertainty of the analyte concentration, and Section 19.6.12 shows how to predict the  
459 uncertainty for a hypothetical measurement. For most basic methods, uncertainty values may be  
460 included for the following input quantities (parameters):

- 461 • Poisson counting statistics (net count rate);
- 462 • Detector efficiency, if applicable;
- 463 • Chemical yield (when applicable) or tracer yield;
- 464 • Sample volume/weight;
- 465 • Decay/ingrowth factor; and
- 466 • Radiometric interference correction factor.

467 Typically, for low-level environmental remediation or surveillance activities, only those input  
468 quantities having an uncertainty greater than one percent significantly contribute to the combined  
469 standard uncertainty. Other than the radiometric interference correction factor and Poisson  
470 counting uncertainties, most input quantity uncertainties normally do not vary as a function of  
471 analyte concentration. At analyte levels near or below the detection limit, the Poisson counting  
472 uncertainty may dominate the method's uncertainty. However, at the action level or above, the  
473 Poisson counting uncertainty may not dominate.

474 When appropriate, the laboratory should determine the method uncertainty over the MQO analyte  
475 concentration range (Section 6.5.5.3), including the action level or other specified analyte  
476 concentration. The laboratory's method validation (Section 6.6) should demonstrate or show  
477 through extrapolation or inference (e.g., from a lower or higher range of concentrations) that this  
478 method uncertainty requirement can be met at the action level or specified analyte concentration  
479 value. Method validation documentation should be provided in the response to the SOW.

#### 480 6.5.5.2 Quantification Capability

481 For certain projects or programs, the project planning team may develop an MQO for the  
482 quantification capability of a method. The quantification capability, expressed as the minimum  
483 quantifiable concentration (MQC), is the smallest concentration of the analyte that ensures a  
484 result whose relative standard deviation is not greater than a specified value, usually 10 percent.  
485 Chapter 19 provides additional information on the minimum quantifiable concentration.

486 MARLAP recommends that, when required, a laboratory analyze each sample to meet the MQC  
487 requirement. For example, if the MQC requirement for <sup>89</sup>Sr is 1.0 Bq/g (with a 10 percent relative

488 standard deviation), the laboratory should select a method that has sufficient chemical yield  
489 (Chapter 19), beta detection efficiency, low background, sample (processing) turnaround time for  
490 a given sample mass, and radioactive decay to achieve a nominal measurement uncertainty of 0.1  
491 Bq/g when the <sup>89</sup>Sr concentration is 1.0 Bq/g. The same forethought that a laboratory gives to  
492 estimating a method's minimum detectable concentration (MDC) for an analyte should be given  
493 to the MQC requirement. The laboratory should consider the uncertainties of all input quantities  
494 (detector efficiency, chemical yields, interferences, etc.), including the Poisson counting  
495 uncertainty when selecting a method. This is an important consideration, because for some  
496 methods, the Poisson counting uncertainty at the MQC level may contribute only 50 percent of  
497 the combined standard uncertainty. Therefore, the laboratory may have to select a method that  
498 will meet the MQC requirement for a variety of circumstances, including variations in matrix  
499 constituents and chemical yields, radionuclide and chemical interferences, and radioactive decay.  
500 In addition, sufficient sample size for processing may be critical to achieving the MQC  
501 specification.

502 During the method validation process, the ability of the method to meet the required MQC  
503 specification should be tested. The method validation acceptance criteria presented in Section 6.6  
504 have been formulated to evaluate the MQC requirement at the proper analyte concentration level,  
505 i.e., action level or other specified analyte concentration.

506 Since the laboratory is to report the analyte concentration value and its measurement uncertainty  
507 for each sample, the project manager or data validator easily can evaluate the reported data to  
508 determine compliance with the MQC requirement. Some projects may send performance testing  
509 (PT) material spiked at the MQC level as a more in-depth verification of the compliance with this  
510 requirement.

### 511 6.5.5.3 Detection Capability

512 For certain projects or programs, the method selected and proposed by the laboratory should be  
513 capable of meeting a required MDC for the analyte/matrix combination for each sample  
514 analyzed. For certain monitoring or research projects, the analyte MDC may be the important  
515 MQC to be specified in the SOW. For such projects, the MDC specification may be based on the  
516 analyte concentration of interest or the state-of-the-art capability of the employed technology or  
517 method. No matter what premise is used to set the value by the project planning team, the  
518 definition of, or the equation used to calculate, the analyte MDC should be provided in the SOW  
519 (Chapter 19). Furthermore, the SOW should specify how to treat appropriate blanks or the  
520 detector background when calculating the MDC. The laboratory should be aware that not all  
521 agencies or organizations define or calculate the MDC in the same manner. It is important for the

522 laboratory to check that the SOW clearly defines the analyte detection requirements. In most  
523 cases, it would be prudent for the laboratory to use a method that has a lower analyte MDC than  
524 the SOW required MDC.

525 In some situations, a radiochemical method may not be robust or specific enough to address  
526 interferences from other radionuclides in the sample. The interferences may come from the  
527 incomplete isolation of the analyte of interest resulting in the detection of the decay emissions  
528 from these interfering nuclides. These interferences would increase the background of the  
529 measurement for the analyte of interest and, thus, increase the uncertainty of the measurement  
530 background. Consequently, an *a priori* MDC, since it is calculated without prior sample  
531 knowledge or inclusion of the interference uncertainties, would underestimate the actual  
532 detection limit for the sample under analysis. Another example of such interferences or increase  
533 in an analyte's background uncertainty can be cited when using gamma-ray spectrometry to  
534 determine  $^{144}\text{Ce}$  in the presence of  $^{137}\text{Cs}$ . The gamma energy usually associated with the  
535 identification and quantification of  $^{144}\text{Ce}$  is 133.5 keV. The gamma energy for  $^{137}\text{Cs}$  is 661.6 keV.  
536 If a high concentration of  $^{137}\text{Cs}$  is present in the sample, the Compton scattering from the 661.6  
537 keV into the 133.5 keV region may decrease the ability to detect  $^{144}\text{Ce}$  by one to two orders of  
538 magnitude over an *a priori* calculation that uses a nominal non-sample specific background  
539 uncertainty. Another example can be cited for alpha-spectrometry and the determination of  
540 isotopic uranium. If some interfering metal is present in unexpected quantities and carries onto  
541 the final filter mount or electrodeposited plate, a substantial decrease in the peak resolution may  
542 occur (resulting in an increased width of the alpha peak). Depending on the severity of the  
543 problem, there may be overlapping alpha peaks resulting in additional interference terms that  
544 should be incorporated into the MDC equation. In order to avoid subsequent analyte detection  
545 issues, it is important for the laboratory to inquire whether or not the project manager has  
546 considered all the constituents (analytes and interferences) present in the sample when specifying  
547 a detection limit for an analyte.

548 The laboratory should include documentation in the response to the SOW that the method  
549 proposed can meet the analyte's MDC requirements for the method parameters (e.g., sample size  
550 processed, chemical yield, detector efficiency, counting times, decay/ingrowth correction factors,  
551 etc.). When practicable, care should be given to ensure the blank or detector background  
552 uncertainty includes contributions from possible anthropogenic and natural radionuclide  
553 interferences. In addition, any proposed screening method should meet the detection limit  
554 requirement in the presence of other radionuclide interferences or natural background  
555 radioactivity. When appropriate or required, the laboratory should test the method's capability of  
556 meeting the required MDC using MVRMs that have analytes and interferences in the expected

557 analyte concentration range. Upon request, the project manager should arrange to provide  
558 MVRMs to the laboratory.

#### 559 6.5.5.4 Applicable Analyte Concentration Range

560 The SOW should state the action level for the analyte and the expected analyte concentration  
561 range. The proposed method should provide acceptable analytical results over the expected  
562 analyte concentration range for the project. Acceptable analytical results used in this context  
563 means consistent method precision (at a given analyte concentration) and without significant  
564 bias. The applicable analyte concentration range may be three or four orders of magnitude.  
565 However, most radioanalytical methods, with proper analyte isolation and interference-decon-  
566 tamination steps, will have a linear relationship between the analytical result and the analyte  
567 concentration. For certain environmental monitoring or research projects, the laboratory should  
568 ensure that there are no instrument or analytical blank background problems. If the background is  
569 not well-defined, there may be an inordinate number of false positive and false negative results.

570 In its response to the SOW, the laboratory should include method validation documentation that  
571 demonstrates the method's capability over the expected range. The laboratory's method  
572 validation (Section 6.6) should demonstrate or show through extrapolation or inference (e.g.,  
573 from a different range of concentrations) that the method is capable of meeting the analyte  
574 concentration range requirement.

#### 575 6.5.5.5 Method Specificity

576 The proposed method should have the necessary specificity for the analyte/matrix combination.  
577 Method specificity refers to the method's capability, through the necessary decontamination or  
578 separation steps, to remove interferences or to isolate the analyte of interest from the sample over  
579 the expected analyte concentration range. Method specificity is applicable to both stable and  
580 radioactive constituents inherent in the sample. Certain matrices, such as soil and sediments,  
581 typically require selective isolation of femtogram amounts of the analyte from milligrams to  
582 gram quantities of matrix material. In these circumstances, the method requires both specificity  
583 and ruggedness to handle variations in the sample constituents.

584 If other radionuclide interferences are known or expected to be present, the SOW should provide  
585 a list of the radionuclides and their expected concentration ranges. This information enables the  
586 laboratory to select and propose a method that has the necessary specificity to meet the MQOs.  
587 As an alternative, the project manager may specify in the SOW the degree of decontamination a  
588 method needs for the interferences present in the samples. If the laboratory is not provided this

589 information, method specificity cannot be addressed properly. The laboratory should ensure that  
590 related information on the matrix characteristics, radiometric or chemical interferences, and  
591 chemical speciation is provided to properly select a method.

#### 592 6.5.5.6 Method Ruggedness

593 Ruggedness is the ability of the method to provide accurate analytical results over a range of  
594 possible sample constituents, interferences, and analyte concentrations, as well as to tolerate  
595 subtle variations in the application of the method by various chemists (EPA, 1998; APHA,  
596 1989). Ruggedness is somewhat qualitative (Chapter 7). Therefore, the desirable parameters of a  
597 rugged method are difficult to specify quantitatively. A ruggedness test usually is conducted by  
598 systematically altering the critical variables (or quantities) associated with the method and  
599 observing the magnitude of the associated changes in the analytical results. ASTM E1169  
600 provides generic guidance on how to conduct method ruggedness tests under short-term, high-  
601 precision conditions. In many cases, a rugged method may be developed over time (typically  
602 when difficulty is experienced applying an existing method to variations in the sample matrix or  
603 when two analysts have difficulty achieving the same level of analytical quality or precision).

604 A laboratory may have several methods for an analyte/matrix combination. Samples from  
605 different geographical locations or having different processes may have completely different  
606 characteristics. Therefore, the laboratory should select a method that is rugged enough to meet  
607 the APSs in the SOW. As indicated in Section 6.6, the prospective client may send site-specific  
608 MVRM samples for the method validation process or for PT samples (Chapter7).

#### 609 6.5.5.7 Bias Considerations

610 As discussed earlier, the proposed method should provide acceptable analytical results over the  
611 expected analyte concentration range for the project. Acceptable results used in this context  
612 means consistent method precision (at a given analyte concentration) and without significant  
613 bias. According to ASTM (E177, E1488, D2777, D4855), “bias of a measurement process is a  
614 generic concept related to a constant or systematic difference between a set of test results from  
615 the process and an accepted reference value of the property being measured,” or “the difference  
616 between a population mean of the measurements or test results and the accepted reference or true  
617 value.” In contrast, ASTM (D2777) defines precision as “the degree of agreement of repeated  
618 measurements of the same property, expressed in terms of dispersion of test results (measure-  
619 ments) about the arithmetical mean result obtained by repetitive testing of a homogeneous  
620 sample under specified conditions.” MARLAP considers bias to be a persistent difference of the  
621 measured result from the true value of the quantity being measured, which does not vary if the

622 measurement is repeated. Normally, bias cannot be determined from a single result or a few  
623 results (unless the bias is large) because of the analytical uncertainty component in the measure-  
624 ment. Bias may be expressed as the percent deviation from a “known” analyte concentration.  
625 Note that the estimated bias, like any estimated value, has an uncertainty—it is not known  
626 exactly.

627 If bias is detected in the method validation process or from other QA processes, the laboratory  
628 should make every effort to eliminate it when practical. Implicitly, bias should be corrected  
629 before using the method for routine sample processing. However, in some cases, the bias may be  
630 very small and not affect the overall data quality. The project manager should review the method  
631 validation documentation and results from internal QC and external PE programs obtained during  
632 the laboratory review process (Chapter 7) and determine if there is a bias and its possible impact  
633 on data usability.

## 634 **6.6 Method Validation**

635 For the purposes of MARLAP, method validation is the demonstration that the radioanalytical  
636 method selected by the laboratory for the analysis of a particular radionuclide in a given matrix is  
637 capable of providing analytical results to meet the project’s MQOs and any other requirements in  
638 the APS. Without reliable analytical methods, all the efforts of the project may be jeopardized.  
639 Financial resources, timeliness, and public perception and confidence are at risk, should the data  
640 later be called into question. Proof that the method used is applicable to the analyte and sample  
641 matrix of concern is paramount for defensibility. The project manager should ensure the methods  
642 used in the analyses of the material are technically sound and legally defensible.

643 The method selected and proposed by the laboratory must be based on sound scientific principles  
644 and must be demonstrated to produce repeatable results under a variety of sample variations.  
645 Each step of the method should have been evaluated and tested by a qualified expert (radio-  
646 analytical specialist) in order to understand the limits of each step and the overall method in  
647 terms of the MQOs. These steps may involve well-known and characterized sample digestion,  
648 analyte purification and decontamination steps that use ion exchange, solvent extraction,  
649 precipitation and/or oxidation /reduction applications. Method validation will independently test  
650 the scientific basis of the method selected for a given analyte and sample matrix.

651 A method validation protocol should be a basic element in the quality system employed by a  
652 laboratory. A proposed method for a specific analyte should be validated in response to the  
653 requirements within a SOW. Demonstration of method performance to meet the MQOs prior to  
654 processing project samples is a critical part of the MARLAP process. As a result of internal QC

655 and external PE programs, most laboratories normally have documentation on the general or  
656 overall performance of a method. As discussed later, this information, depending on many  
657 aspects, may be sufficient in meeting the method validation criteria.

658 Methods obtained from the literature, from recognized industry standards (ASTM, ANSI, APHA)  
659 or government method manuals may have been validated for certain general applications by the  
660 developing or issuing laboratory. However, other laboratories would have to validate the method  
661 for specific project use.

### 662 **6.6.1 Laboratory's Method Validation Protocol**

663 During the discussion on method validation, certain terms are used. These include MVRM, QC,  
664 and PT materials. QC samples and programs are related to those samples or processes that are  
665 used to evaluate the quality of the analytical results for the fundamental purpose of directly  
666 controlling the quality of the analytical process by initiating control mechanisms. PT materials  
667 are materials prepared for use in a PE program or for validating methods. MVRM refers to site-  
668 specific materials that have the same or similar chemical and physical properties as the proposed  
669 project samples. Although the MVRM is the most appropriate material for testing a laboratory's  
670 project-specific performance, or for validating a method for a particular project, its availability  
671 may be limited depending on the project manager's ability to supply such material.

672 The laboratory's method validation protocol should include the evaluation of the method for  
673 project specific MQOs for an analyte or generic quality performance criteria as well as other  
674 generic parameters. With a properly designed method validation protocol, important information  
675 may be ascertained from the analytical results generated by the method validation process.

676 The parameters that should be specified, evaluated, or may be ascertained from the analytical  
677 results generated by the method validation process are listed below:

- 678     ◇ Defined Method Validation Level (Table 6.1)
- 679     ◇ APSs including MQOs for each analyte/matrix
  - 680         ○ Chemical or physical characteristics of analyte when appropriate
  - 681         ○ Action level (if applicable)
  - 682         ○ Method uncertainty at a specific concentration
  - 683         ○ MDC or MQC
  - 684         ○ Bias (if applicable)
  - 685         ○ Applicable analyte concentration range including zero analyte (blanks)
  - 686         ○ Other qualitative parameters to measure the degree of method ruggedness or specificity

- 687     ◇ Defined matrix for testing, including chemical and physical characteristics that approximate
- 688         project samples
- 689     ◇ Selected project-specific or appropriate alternative matrix PT samples, including known
- 690         chemical or radionuclide interferences at appropriate levels
- 691     ◇ Defined sample preservation
- 692     ◇ Stated additional data testing criteria (such as acceptable chemical/radiotracer yield values)

693     In order to properly demonstrate that a method will meet project MQOs, the method should be  
694     evaluated over a range of analyte concentrations. The analyte concentration range of the matrix  
695     spikes (covering the testing levels) used for method validation should cover the expected analyte  
696     concentration range for the project (Section 6.5.5.3), with the middle of the range set near the  
697     action level. At the upper end of the range, the method validation samples should be analyzed to  
698     have a Poisson counting uncertainty between 1 percent (ANSI N42.23) and 3 percent (1 sigma).  
699     Keeping the Poisson uncertainty <3 percent (1 sigma) will ensure the observed precision, as  
700     measured by multiple samples, is not dominated by the Poisson counting uncertainty. In addition,  
701     anticipated or known chemical and radionuclide interferences should be added in the appropriate  
702     “interference to analyte” activity or concentration ratio. Appropriate method blanks (also  
703     containing interferences when practical) should be analyzed concurrently with the matrix spikes  
704     to determine analyte interferences or biases near the detection limit.

705     The number of samples for the method validation process varies according to the method  
706     validation level needed. As proposed in Table 6.1, the number of samples may vary from 6 to 21,  
707     depending on the robustness of the method validation.

## 708     **6.6.2 Tiered Approach to Validation**

709     While MARLAP recommends that as each new project is implemented, the methods used in the  
710     analysis of the associated samples undergo some level of validation, it is the project manager's  
711     responsibility to assess the level of method validation necessary. Although the end result of  
712     method validation is to ensure that the method selected meets the MQOs for an analyte/matrix,  
713     the extent of the validation process depends on whether the laboratory should elect to develop a  
714     new method or whether there is an existing validated method available that can be adapted or  
715     validated for another specific project need. Therefore, MARLAP recommends that a tiered  
716     approach be taken for method validation. The recommended protocols to be considered for  
717     existing methods are provided in the next four sections, requiring from least to most effort: no  
718     additional validation, modification of a method for a similar matrix, new application of a method,  
719     and newly developed or adapted methods. Table 6.1 consolidates recommended validation  
720     requirements from various government agencies and consensus organizations. The suggested

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721 levels of validation are indicative of the modification required of the method. It should be noted  
 722 that the method validation requirements of Table 6.1 permit the laboratory to use internal QC, PE  
 723 program, or site-specific MVRM samples, or permit the project manager may provide PT, PE  
 724 program, or site-specific MVRM samples for the laboratory to use. Sometimes, a project  
 725 manager may provide PT samples as part of the qualifying process. In this case, the project  
 726 manager should ensure consistency with the method validation requirements of Table 6.1.

727 **TABLE 6.1 — Tiered method validation approach**

728 <b>Validation Level</b>	<b>Application</b>	<b>Sample Type</b>	<b>Acceptance Criteria*</b>	<b>Levels (Concentrations)**</b>	<b>Replicates</b>	<b># of Analyses</b>	
730 <u>A</u> 731 Without 732 Additional 733 Validation	Existing Validated Method	–	Method previously validated (by one of Validation Levels B through H)	–	–	–	
734 <u>B</u>	Similar Matrix	Internal QC	Measured value within $\pm 3 u_{MR}$ of known value	3	3	9	
735 <u>C</u>	Similar Matrix/ New Application	External PE		3	7	21	
736 <u>D</u> 737 ASTM D2777	New Application	Internal QC		Three to five groups of two samples with concentrations within 20% of each other			6-10
738 <u>E</u> 739 ASTM D2777	New Application	External PE					6-10
740 <u>F</u> 741 EPA 742 Equivalency	New Application/ newly Developed or Adapted Method	MVRM Samples		3	7	21	
743 <u>G</u> 744 ASTM D2777	Newly Developed or Adapted Method	MVRM Samples		Three to five groups of two samples with concentrations within 20% of each other			6-10
745 <u>H</u> 746 ASTM D2777 747 (Involves the 748 two testing 749 protocols stated 750 to the right)		MVRM Samples for both protocols	Measured value within $\pm 3 u_{MR}$ of known value	Three to five groups of two samples with concentrations within 20% of each other			6-10
			Each measured value $\leq 30\%$ of known at 5 times MDC	Three to five groups of two samples with concentrations within 20% of each other bracketing 5 times the MDC			6-10

751 \* Assumes that each sample is counted to have a Poisson counting uncertainty of < 3% (sigma) when the analyte concentration is  
 752 near the action level or MQC. This criterion is applied to each analysis in the method validation, not to the mean of the analyses.  
 753  $u_{MR}$  is the required method uncertainty at the action level or required concentration.  $u_{MR}$  is an absolute value for concentrations  
 754 less than the action level and a relative (%) value for concentrations greater than the action level. In the absence of a specified  
 755 value, the default of  $\pm 3 u_{MR}$  acceptance criterion is: each measured value at the action level or other specified concentration must  
 756 be within  $\pm 30\%$  of known value. See references for ASTM D2777.

757 \*\*Concentration levels should cover the expected analyte concentration range for a project including the action level  
 758 concentration. A set of three blanks (not considered a level) should be analyzed during the method validation process.

759 The tiered approach to method validation outlined Table 6.1 was developed to give the project  
760 manager flexibility in the method validation process according to the project requirements. The  
761 degree of method validation increases from the lowest (Level A) to the highest (Level H). The  
762 table's acceptance criteria for the validation process for a given project are based on the MQO for  
763 the method uncertainty at the action level or other stated concentration. Each of the validation  
764 levels evaluates the proposed method over the expected concentration range of the analytes and  
765 interferences. The acceptance criterion of having each analytical result meet the  $\pm 3 u_{MR}$  of the  
766 known value ensures a high degree of confidence that a method will meet the required method  
767 uncertainty (MQO) at the action level or other specified concentration. (See Appendix C for the  
768 definition of the method uncertainty at the action level or other stated concentration,  $u_{MR}$ .) In  
769 addition to evaluating the method uncertainty, the method should be evaluated for bias.

770 During the method validation process, the laboratory should ensure that the observed precision  
771 for the samples processed is consistent with the estimated individual sample measurement uncer-  
772 tainty. An evaluation should be conducted for replicate sample analyses that have the same  
773 approximate relative measurement uncertainties. Samples having analyte concentrations within a  
774 narrow range of one another (ASTM D2777 Youden Pairs) may be considered when their  
775 relative measurement uncertainties are approximately the same. If the estimated measurement  
776 uncertainty of a given sample is much smaller than the observed method precision for the  
777 replicate samples, then the laboratory may not have properly estimated the uncertainty of one of  
778 the input quantities (parameters) or has omitted an input quantity in the measurement uncertainty  
779 (combined standard uncertainty).

#### 780 6.6.2.1 Existing Methods Requiring No Additional Validation

781 For completeness, it is necessary to discuss the possibility that a previously validated method of  
782 choice requires no additional validation (Level A of Table 6.1) for a specific project use. As  
783 noted in the table, the method has undergone some level (Level B through H) of previous  
784 validation. It may be that the samples (matrix and analyte specific) associated with a new project  
785 are sufficiently similar to past samples analyzed by the same laboratory that the project manager  
786 feels additional validation is unwarranted. The decision to use Level A method validation should  
787 be made with caution. While the sampling scheme may be a continuation, the analytical  
788 processing capabilities at the laboratory may have changed sufficiently to merit limited method  
789 validation. Without some level of method validation, the project manager has no assurance that  
790 the analytical laboratory will perform to the same standards as an extension of the earlier work.

791 6.6.2.2 Use of a Validated Method for Similar Matrices

792 When a previously validated method is to be used in the analysis of samples that are similar to  
793 the matrix and analyte for which the method was developed, MARLAP recommends that  
794 validation of the method be implemented according to Level B or C of Table 6.1. These levels  
795 will provide a reasonable assurance to both the laboratory and the project manager that the  
796 method will meet the required MQOs associated with the project. Level B may be used if the  
797 laboratory has the capability to produce internal QC samples. When the laboratory does not have  
798 the capability to produce internal QC samples, the Level C validation protocol should be used.  
799 However, PE programs may not provide the necessary matrices needed for the Level C validation  
800 protocol.

801 Since a method inherently includes initial sample preparation, projects that have severe  
802 differences in analyte heterogeneity may require a moderate change in a radiochemical method's  
803 initial sample treatment. A change in the method to address the increased heterogeneity of the  
804 analyte distribution within the sample may require another method validation depending on the  
805 robustness of the method and the degree of analyte heterogeneity.

806 6.6.2.3 New Application of a Validated Method

807 Methods that have been validated for one application normally require another validation for a  
808 different application, such as a different sample matrix. In addition, the MQOs may change from  
809 one project to another or from one sample matrix to another. The validation process for an  
810 existing validated method should be reviewed to ensure applicability of the new (which can be  
811 more or less restrictive) measurement quality objectives. In most cases, applying an existing  
812 method for one matrix to another matrix is not recommended without another method validation.  
813 MARLAP recommends, based on the extent of the modification and the difficulty of the matrix,  
814 that Levels C-F of Table 6.1 be used to validate the performance of the modified method. The  
815 following paragraphs and the next section provide information on whether a validated method  
816 requires a slight modification or a complete revision.

817 Validation of an existing method for a different application depends on the extent of the  
818 departure from the original method application, in terms of:

- 819 • Dissimilarity of matrices;
- 820 • Chemical speciation of the analyte or possible other chemical interference;
- 821 • Analyte, chemical or radiometric interferences;
- 822 • Complete solubilization of the analyte and sample matrix; and

- 823 • Degree of analyte or sample matrix heterogeneity.

824 When the chemical species of the analyte in a sample from a new project varies from the  
825 chemical species for which the method was validated, then the method will have to be altered  
826 and another validation performed. An example would be when a method had been developed to  
827 extract iodide via ion exchange chromatography but the new application may have I<sub>2</sub>, iodate, or  
828 iodide in the sample. Another example would be the initial development of a method for Pu in  
829 soil generated from liquid effluents using acid dissolution and then trying to apply the same  
830 method to high-fired plutonium oxide in soil. For these two examples, if the original methods  
831 were to undergo the validation process for the new application, definite deficiencies and poor  
832 results would become evident. Portions of the original method would have to be modified to  
833 address the chemical speciation problems. The modified method requires validation to ensure  
834 that the measurement quality objectives for the new application can be met.

835 When additional analyte, chemical, or sample matrix interferences are known to exist for a new  
836 application compared to the old method application, the previously validated method should  
837 undergo another validation, depending on the degree of interference and the problems anticipa-  
838 ted. For example, applying a method used for the analysis of an analyte in an environmental  
839 matrix containing few interfering radionuclides would typically be inappropriate for the analysis  
840 of process waste waters containing many interfering radionuclides at high concentrations. In  
841 essence, the degree of decontamination (degree of interference removal) or analyte purification  
842 (isolation of the analyte from other radionuclides) necessary for one application may be  
843 completely inadequate or inappropriate for another application (an indication of method  
844 specificity).

845 Another example would be the use of a method for soil analysis employing <sup>234</sup>Th as a radiotracer  
846 for chemical yield for the isotopic analysis of thorium when the soil also has a high concentration  
847 of uranium. <sup>234</sup>Th is an inherent decay product of <sup>238</sup>U and will exist in the sample as a natural  
848 analyte, thus creating erroneous chemical yield factors. A third example would be the application  
849 of a <sup>90</sup>Sr method developed for freshwater to seawater samples for which the amount of chemical  
850 interferences and ambient Sr levels are extensive. For these three examples, conducting the  
851 validation process for the original methods for the new applications would, depending on the  
852 severity of the analyte and chemical interference, illustrate method deficiencies and the inability  
853 to meet measurement quality objectives.

854 Some matrices and analytes may be solubilized easily through acid dissolution or digestion. For  
855 some applications, the analyte of interest may be solubilized from the sample matrix through an  
856 acid extraction process. The applicability of such methods should be carefully chosen and, most

857 important, the method must be validated for each application. Definite problems and  
858 misapplication can be the result of using an acid extraction process when a more robust complete  
859 sample dissolution is necessary.

#### 860 6.6.2.4 Newly Developed or Adapted Methods

861 MARLAP recommends that methods under development by the laboratory or adapted from the  
862 literature that have not been previously validated for a project be validated according to Levels  
863 F to H of Table 6.1. These levels provide the most comprehensive testing of method perfor-  
864 mance. For low-level environmental surveillance applications, it may be advantageous to use the  
865 second set of requirements of Level H (each measured value must be within  $\pm 30$  percent of the  
866 known value at 5 times the MDC) as part of the other validation levels as well. This requirement  
867 will assess the method's ability to perform at the concentration ranges more commonly associated  
868 with environmental samples. When process knowledge is available or the matrix under  
869 consideration is unique or site-specific, it is best to validate the method using the matrix (e.g.,  
870 MVRM) under consideration. This is extremely important for process/effluent waters versus  
871 laboratory deionized water and for various heavy metal radionuclides in soils or sediments when  
872 compared to spiked sand or commercial topsoil. For site-specific materials containing severe  
873 chemical and radionuclides interferences, many methods have been unable to properly address  
874 the magnitude of interferences.

#### 875 **6.6.4 Method Validation Documentation**

876 Method validation, depending on the required level of validation, can be accomplished by the  
877 project manager sending PT samples to the laboratory or by the laboratory using internal or  
878 external PT/QC samples. When PT samples are sent to a laboratory to evaluate or validate the  
879 laboratory's method and capabilities, the appropriate technical representative should retain all  
880 records dealing with applicable method validation protocols (Section 6.6.3), PT sample  
881 preparation certification, level of validation (from Table 6.1), results, and evaluations. The  
882 laboratory should provide the necessary documentation to the project manager for these PT  
883 samples as required by the SOW. The laboratory should request feedback from the project  
884 manager as to the method performance. This information, along with the sample analytical  
885 results documentation, should be retained by the laboratory for future method validation  
886 documentation.

887 When the laboratory conducts its own method validation, all records, laboratory workbooks, and  
888 matrix spike data used to validate an analytical method should be retained on file and retrievable  
889 for a specified length of time after the method has been discontinued.

890 **6.7 Analyst Qualifications and Demonstrated Proficiency**

891 The required level of qualification of an analyst is commensurate with the degree of difficulty  
892 and sophistication of the method in use. The selection of the analyst for the method application is  
893 typically determined initially on experience, education and proven proficiency in similar  
894 methods. Basic guidance for the minimum education and experience for radioassay laboratory  
895 technicians and analysts has been provided in Appendix E and ANSI N42.23.

896 For radiochemical methods, there may be several analysts involved. At most major laboratories,  
897 different individuals may be involved in the sample preparation, radiochemistry, and radiation  
898 detection aspects of the method. In these cases, the entire staff involved in the method should  
899 undergo method proficiency tests to demonstrate their ability to meet quality requirements and  
900 performance goals. The staff involved in the initial validation of an acceptable method would be  
901 considered proficient in their particular role in the method application and the results of their  
902 performance should be documented in their training records.

903 Successful proficiency is established when the performance of the analyst or staff meet  
904 predefined quality requirements defined in the laboratory's quality system or a SOW, as well as  
905 processing goals. Parameters involved in operational processing goals are typically turnaround  
906 time, chemical yields, frequency of re-analyses (percent failure rate), and frequency of errors.

907 The continued demonstrated analyst proficiency in the method is usually measured through the  
908 acceptable performance in internal QC and external PE programs associated with routine sample  
909 processing.

910 **6.8 Method Control**

911 Method control is an inherent element of a laboratory's quality system. Simply stated, method  
912 control is the ongoing process used to ensure that a validated method continues to meet the  
913 expected requirements as the method is routinely used. Method control is synonymous with  
914 process control in most quality systems. For a laboratory operation, method control can be  
915 achieved by the application of the following:

- 916 • Controlled method manual (latest revision and signature sign-off);
- 917 • NIST traceable calibration standards and the conduct of an instrument QC program that  
918 properly evaluates the variable parameters on an appropriate frequency;

- 919 • Radiotracers or chemical yields for each sample and the evaluation of the measured chemical  
920 yield values to expected ranges;
- 921 • Internal QC and external PT samples to determine deviations from expected quality  
922 performance ranges;
- 923 • Standard operating procedures for troubleshooting “out of control” situations; and
- 924 • Problem reporting, corrective action, and quality improvement process.

925 The above method control elements are typically addressed in the quality manual of the  
926 laboratory or the project plan document for the project under consideration. Refer to Chapter 18  
927 for additional information.

## 928 **6.9 Continued Performance Assessment**

929 The assessment of a laboratory’s continued performance is covered in detail in Chapter 7.  
930 However, it is important to briefly discuss certain aspects of evaluating a method’s continued  
931 performance from a laboratory’s perspective.

932  
933 In order to properly perform statistical analyses or compliance interpretation of the analytical data  
934 produced from an analytical method, it is assumed that data quality does not vary significantly.  
935 Therefore, the user of the data expects that the overall data quality will not change throughout the  
936 program or project. From a laboratory management perspective, a performance indicator system  
937 should be in place that assesses and provides feedback on the quality of the routine processing.  
938 The most useful and cost-effective means of assessing a method’s performance is through the  
939 implementation of internal QC or external performance evaluation programs or both. Of course,  
940 it can be argued that method assessment through a QC or PE program evaluates the combined  
941 performance of the method and the analyst. However, statistical and inferential interpretation of  
942 the QC/PE data can provide insight into whether the method is failing or whether an analyst is  
943 underperforming. Chapters 7 and 18 and Appendix C provides guidance on quality control  
944 programs and the use of the internal laboratory QC or external PE data to assess the laboratory’s  
945 performance in meeting performance criteria.

946 The laboratory management should use the internal QC program to detect and address  
947 radioanalytical issues before the client does. Many SOWs require the use of internal QC samples  
948 for every batch of project samples (Chapter 18). In effect, the client is essentially setting the level  
949 of internal quality control and the frequency of method performance evaluation. It should be

950 recognized that an internal QC program evaluates method performance related to the initial  
951 calibrations or internal “known values.” An external NIST-traceable PE program will explain  
952 method biases relative to the national standard or to the agency’s PE program.

953 Some users of laboratory services have developed “monitoring” laboratory programs (ANSI  
954 N42.23). For these programs, the user engages a recognized independent monitoring laboratory  
955 to intersperse double- and single-blind external PT materials into batches of normal samples  
956 submitted to a laboratory. The complexity and frequency of the monitoring laboratory PT  
957 samples vary among programs, projects, and Federal and state agencies. An external double-blind  
958 PE program conducted by a monitoring laboratory using site-specific matrices probably provides  
959 the most realistic estimate of the method’s or laboratory’s true performance. When the  
960 monitoring laboratory is traceable to NIST, either directly or through a NIST reference laboratory  
961 (ANSI N42.23), the monitoring laboratory program will provide an estimate of any method bias  
962 as related to the national standard.

963 Method performance can also be determined, although on a less frequent basis, through the  
964 laboratory’s participation in the various PE programs. For a laboratory providing services to  
965 government agencies, the participation in such programs is typically a requirement. The PE  
966 programs commonly send out non site-specific PT materials on a quarterly or semiannual basis.

967 The laboratory’s performance in certain PE program is public knowledge. Such information is  
968 useful to project managers in selecting a laboratory during the laboratory selection and qualifying  
969 processes. Similar to the monitoring laboratory, when the laboratory conducting the PE program  
970 is traceable to NIST, either directly or through a NIST reference laboratory (ANSI N42.23), the  
971 PE program may provide an estimate of the bias as related to the national standard as well as the  
972 precision of the method, depending on the distribution of replicate samples.

973 Some projects require that all analytical results received from a laboratory undergo a data  
974 verification and validation process. Chapter 8 provides more detail on these processes. When  
975 properly conducted, certain aspects and parameters of the method can be assessed during the data  
976 verification and validation process.

977 Internal and external audits/assessments are also key elements in a laboratory’s quality system to  
978 assess the continuing performance of a method (Chapter 7). The level and frequency of the audits  
979 and assessments typically vary according to the magnitude and importance of the project and on  
980 the performance of the laboratory. Another quality system element that is very effective is a self-  
981 assessment program. A functioning and effective self-assessment program may identify

982 weaknesses or performance issues more readily and timely than formal internal and external  
983 audits.

## 984 **6.10 Documentation To Be Sent to the Project Manager**

985 The documentation related to the life cycle of a method application is essentially the information  
986 gathered during the use of the method. A formal method documentation program is unnecessary  
987 since the information should be part of the quality system documentation. Documented  
988 information available from the quality system, related to a method's development, validation, and  
989 control, include the following:

- 990 • Method validation protocol and results;
- 991 • Analyst training and proficiency tests;
- 992 • Method manual control program;
- 993 • Instrument calibration and QC results;
- 994 • Internal QC and external PT sample results;
- 995 • Internal and external assessments; and
- 996 • Corrective actions.

997 Data verification and validation information should be kept available and retained for those  
998 projects requiring such processes. In addition to QA documentation, the analytical results, either  
999 in hard copy or electronic form, should be available from the laboratory for a specified length of  
1000 time after the completion of a project.

### 1001 **Summary of Recommendations**

- 1002 • MARLAP recommends the performance-based approach for method selection.
- 1003 • MARLAP recommends that only methods validated for a project's application be used.
- 1004 • MARLAP recommends that a SOW containing the MQOs and analytical process  
1005 requirements be provided to the laboratory.
- 1006 • MARLAP recommends that the SOW include the specifications for the action level and  
1007 the required method uncertainty for the analyte concentration at the action level for each  
1008 analyte/matrix.

- |      |  |
|------|--|
| 1009 | <ul style="list-style-type: none"><li>• MARLAP recommends that as each new project is implemented, the methods used in the analysis of the associated samples undergo some level of validation.</li><li>• MARLAP recommends that a tiered approach (Table 6.1) be taken for method validation.</li></ul> |
| 1010 |  |
| 1011 |  |

1012 **6.11 References**

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