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National Representative Sample of Small Public Water Systems: Statistical Design and State Plans for the Unregulated Contaminant Monitoring Regulation

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Foreword

Under §1445(a)(2)(A) of the Safe Drinking Water Act (SDWA), as amended in 1996, the Environmental Protection Agency (EPA) is to promulgate regulations for an unregulated contaminant monitoring program by August 1999. The existing unregulated contaminant monitoring program has been performed according to the program described in CFR 141.40. The 1996 SDWA Amendments direct a substantially revised Unregulated Contaminant Monitoring Regulation (UCMR). The revised UCMR has a new list of contaminants and changes the number of public water systems (PWSs) that must conduct monitoring and the frequency and schedule for monitoring.

This document provides technical background information on the statistical process used to select the nationally representative sample of small public water systems (that is, those serving 10,000 or fewer people) that will be included in the revised UCMR Program. The data collected through this program will be used to support the development of the Contaminant Candidate List (CCL), to support the Administrator's determination of whether to regulate a contaminant, and to develop regulations. The revised monitoring program is one of the cornerstones of the sound science approach to future drinking water regulation that is an aim of the 1996 SDWA Amendments.

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Disclaimers

This guidance document is designed to implement national policy concerning this UCMR Program. The document does not, however, substitute for the SDWA or EPA's regulations nor is this document itself a regulation. Thus, it cannot impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA and State decision makers retain the discretion to adopt approaches on a case-by-case basis that differs from this guidance where appropriate. EPA may change this guidance in the future.

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Acknowledgments

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1. Introduction

Under Section 1445(a)(2) of SDWA, as amended in 1996, the Environmental Protection Agency (EPA) is required to establish criteria for a revised monitoring program for unregulated contaminants and, by August 11, 1999, to publish a list of contaminants to be monitored. To conform to the 1996 Amendments, EPA has proposed substantial revisions in its proposed Unregulated Contaminant Monitoring Regulation (UCMR), described in the UCMR Preamble and Rule (64 FR _____). The purpose of the UCMR Program is to collect unregulated contaminant occurrence data to help determine which of those contaminants EPA should regulate based on the concentrations of the contaminant(s) in public water systems and their potential adverse health effects through contaminant exposure.

This proposed rule will take the place of the regulations currently in 40 CFR §§141.35, 141.40, and 142.15(c)(3) and modify §142.16. The revisions cover the following: (1) the frequency and schedule for monitoring based on public water system (PWS) size, water source, and likelihood of finding the contaminants; (2) a new shorter list of contaminants to be monitored, (3) procedures for selecting and monitoring a national representative sample of PWSs serving 10,000 or fewer people, and (4) procedures for placing the monitoring data in the National Drinking Water Contaminant Occurrence Database (NCOD), as required under Section 1445. The data generated by this rule will be used to support the development of the Contaminant Candidate List (CCL), the Administrator's determination of whether or not to regulate a contaminant, and to develop drinking water regulations. The proposed revised UCMR Program is a cornerstone of the sound science approach to future drinking water regulation, which is one of the aims of the SDWA Amendments.

The purpose of this document is to describe the general statistical design, rationale, and specific methods used to select the representative sample of small systems that are required to undertake UCMR monitoring. Portions of this document also describe how this process relates to the UCMR monitoring plans of individual States. Under the UCMR, the listed unregulated contaminants will be monitored between 2001-2005. All large PWSs (systems serving more than 10,000 people) are required to monitor for these unregulated contaminants. Section 1445(a)(2) of SDWA mandates that only a representative sample of small PWSs (systems serving 10,000 or fewer people) may be required to monitor under the UCMR. The representative sample must be of adequate size and quality to obtain the necessary and valid contaminant occurrence information upon which to base regulatory determinations while minimizing burden to the water system.

The objective of the statistical approach for the UCMR is to estimate contaminant exposure and occurrence in a nationally representative sample of small systems which will enable extrapolations of exposure and occurrence nationwide. For contaminant exposure assessments (that is, the fraction of population that is exposed to a contaminant), the representative sample design is primarily population-weighted. However, information on contaminant occurrence is also necessary. The context of occurrence (for example, the size of a water system or its water source) is a factor when evaluating potential future regulatory implementation. Therefore, the representative sampling design incorporates a stratified sampling approach and allocates some samples among strata to enable evaluations of occurrence relative to system size (based on population served), water source type (surface water or groundwater) and, to some degree, geographic distribution. Although this statistical design is not strictly optimal for either exposure or occurrence, the design still meets the data quality objective criteria for exposure estimates (99% confidence level with ±1% error, at 1% exposure) while providing important occurrence estimates for categories of small systems.

1.1 Background

There are three major components of the proposed UCMR Program: Assessment Monitoring, Screening Surveys, and Pre-Screen Testing. Assessment Monitoring will be conducted in the first three years (2001-2003) of the five-year UCMR cycle (2001 to 2005), and will be conducted for the contaminants with currently available analytical methods. The Assessment Monitoring contaminants are listed in §141.40(a)(3) Table 1, UCMR (1999) List 1. Assessment Monitoring will be required for all large systems and a representative sample of small systems. A statistically representative, stratified random sample will be used to select 800 small systems to undertake Assessment Monitoring (See Section 7). Analytical monitoring results from Assessment Monitoring will be used for evaluations of contaminant exposure and occurrence.

Screening Surveys will be conducted by a statistically selected subset of the large and small systems conducting Assessment Monitoring. The Screening Surveys (see Section 8) will be conducted between 2001 and 2003 for contaminants listed in §141.40(a)(3) Table 1, UCMR (1999) List 2. The analytical methods for these contaminants currently are being refined. Analytical monitoring results from Screening Surveys will be used for evaluations of contaminant occurrence in water systems. Screening Survey results will help guide decisions of whether or not to move List 2 contaminants to List 1 for Assessment Monitoring.

Pre-Screen Testing will be conducted by up to 200 small and large systems that are determined to be most vulnerable to occurrence of the contaminants listed in §141.40(a)(3) Table 1, UCMR (1999) List 3. The Pre-Screen Testing (see Section 9) will be conducted in 2003 or 2004. The analytical methods for the Pre-Screen Testing contaminants currently are in the early stages of development. Pre-Screen Testing will be conducted to determine whether the analytical methods in early development can provide adequate results in conditions under which the contaminants are most likely to occur.

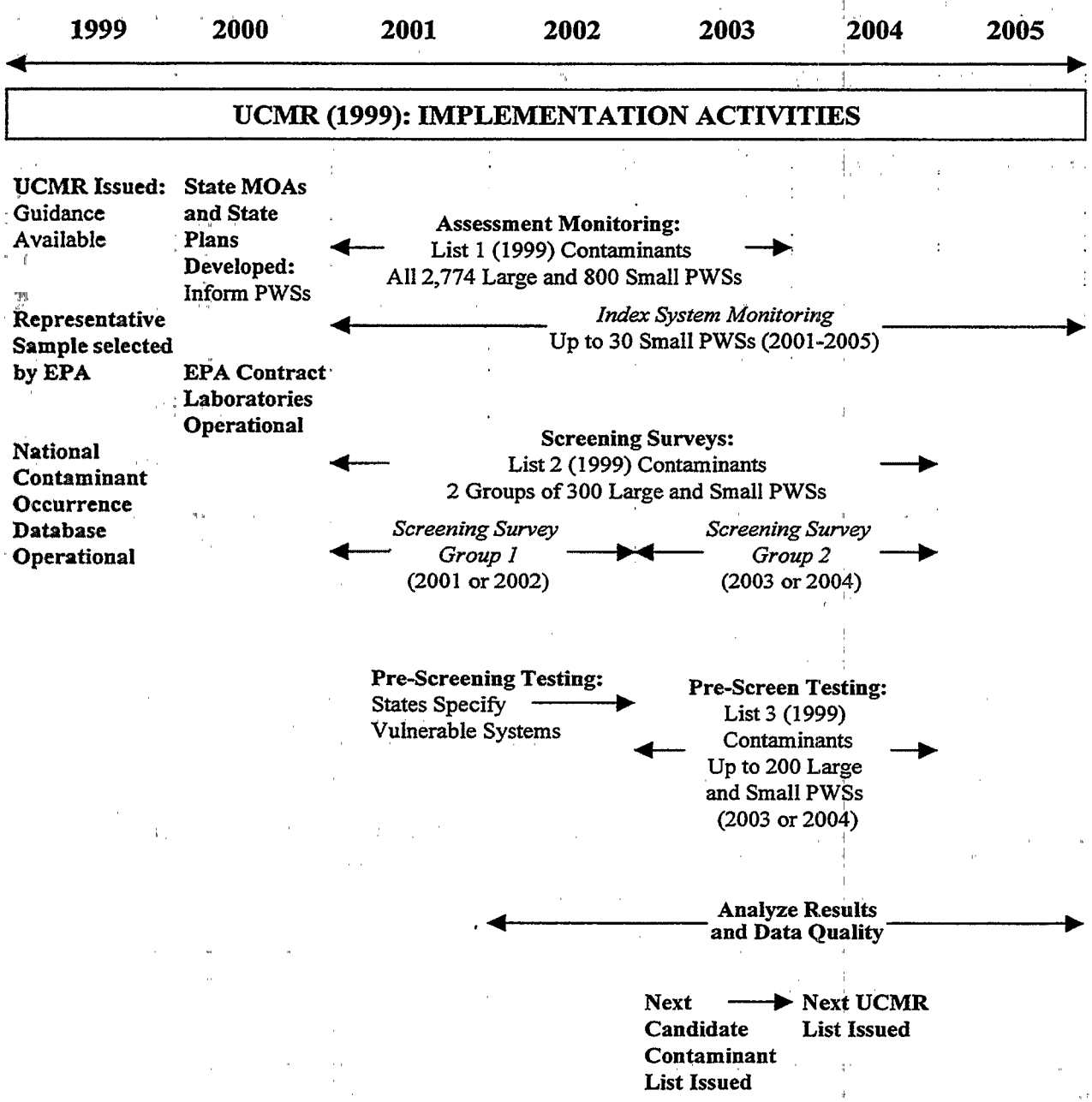
Figure 1 illustrates the time-line for the national representative sample selection, Assessment Monitoring, Screening Surveys, Pre-Screen Testing and other related UCMR activities.

Under SDWA and the UCMR, States can develop State Monitoring Plans (State Plans) for small system monitoring. Discussions with States and other stakeholders indicate the need to select a representative sample of systems across all States to ensure both confidence in the UCMR results and a comprehensive spatial distribution. To ensure that the sample is representative of the nation and to reduce the burden on the States, EPA will statistically select a nationally representative sample of systems serving 10,000 or fewer people for the UCMR. To further reduce the burden on States, EPA will directly implement the UCMR.

The States can participate in the program through the State Plan as established by Memorandums of Agreement (MOAs) with EPA. The State Plans will be established by States that enter into MOAs. Through the MOAs, States take a partnership role in the development of the State Plan and implementation of the UCMR. All steps involved with sample selection described throughout this document assume that a State has entered into an MOA with the appropriate EPA Regional Office.

As described later in this document, a list of the statistically-selected systems will first be provided by EPA to the States. The list will be comprised of an "initial list" and "replacement list" of systems. These lists will be provided to the States for their review and inclusion in their State Plans. States can either (1) respond by accepting the primary list as their representative plans, or (2) propose an alternative plan by selecting other system(s) from the replacement list, in cases where EPA's initial

Figure 1. Time-line for National Representative Sample Selection, Assessment Monitoring, Screening Surveys, Pre-Screen Testing and other Related UCMR Activities.



plan identifies system(s) that no longer exist, because of merger or closure, or have switched to purchased water.

One-third of the systems in each State Plan will be sampled each year over the three-year Assessment Monitoring period. EPA will pay for the testing costs for the Assessment Monitoring of small systems (and will also pay for the costs of the Screening Survey and Pre-Screen Testing programs) as long as the systems are part of the State Plans. EPA may also modify the size of the representative sample to reflect available funds.

Additionally, EPA will select up to 30 small PWSs as "Index" systems and will monitor these systems each year during the five year UCMR Listing Cycle. Index systems are a subset of the national representative sample and will be selected randomly from the sample. Index system monitoring will provide added quality control and more detailed information on temporal variations in contaminant occurrence, and on environmental and operating conditions of small systems so that future regulations can better reflect small system characteristics and conditions.

Further information about the UCMR Program can be found in the UCMR Preamble of the final Rule (64 FR _____) , and supporting guidance and technical documents. These documents are available from the EPA Water Docket, (202) 260-3027, Docket Number W-98-02. General information can also be obtained from the EPA Safe Drinking Water Hotline, (800) 426-4791, or through the EPA Office of Ground Water and Drinking Water Internet Home page at www.epa.gov/ogwdw.

2. Selecting the Statistical Population for Systems Serving 10,000 or Fewer People

2.1 Determining the Population

The total population of small PWSs is comprised of community water systems (CWSs), non-transient non-community water systems (NTNCWSs) and transient non-community water systems (TNCWSs). Two categories of PWSs are being excluded from the population for selecting the sample. PWSs that purchase their entire water supply from another PWS are generally exempt from the regulation, since monitoring at these systems could result in double counting of systems using the same source.[1] Additionally, TNCWSs will be excluded from the UCMR, since projecting contaminant exposure from monitoring results is difficult and inconclusive due to the transient nature of the population that use these sources of drinking water.

EPA estimates that there are approximately 65,636 non-purchased CWSs and NTNCWSs, based on the 1997 Safe Drinking Water Information Systems' (SDWIS) PWS inventory.[2] Table 1 illustrates the national number of non-purchased CWSs and NTNCWSs serving 10,000 or fewer people in each size category (serving 25 to 500, 501 to 3,300 and 3,301 to 10,000 people) by the source water type (ground or surface water), from the SDWIS inventory as of January 1997. These systems provide an example of the statistical population from which the national representative sample will be drawn. The actual sample used for UCMR sampling will be derived from the most current SDWIS inventory available at the time of sample selection, so the actual number of systems in Table 1 may change slightly.

2.2 Stratifying the Population

In developing the representative sample, EPA must consider factors such as (1) geographic location, (2) population served, and (3) water source. The UCMR accomplishes this at various levels by stratifying the sample by categories of population served, allocating samples proportionately to each State by system size, and then by water source (surface water and ground-water supplied systems). NTNCWSs are selected as a separate category since these systems may be a significant source of water consumed by residents of a community.

Sources of water may not be evenly distributed across any given State. Cities transfer water across watershed boundaries, or move water from one State to another. To account for the proportion of the population served by a specific type of water source (surface or ground water), EPA proposes to define "geographic location" in the representative sample as the location of the water source and stratify the sample further by source of water supply (ground and surface water). For example, if 10 percent of the population in a State obtains their water from surface water supplied PWSs that

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[1] Note that purchased water systems may be required to monitor UCMR (1999) List 2 and UCMR (1999) List 3 microbiological contaminants where the system is considered to be the distribution line with the maximum residence time.

[2] For the purposes of estimates in this report, the SDWIS January 1997 inventory of PWSs is used. EPA will re-compute the sample size at the time of actual statistical sample selection using the most current inventory.

Table 1. Systems Serving 10,000 or Fewer People

Population Served	Total Population Served Nationally					Number of Non-purchased PWSs				
Size Category	CWSs		NTNCWSs		Total	CWSs		NTNCWSs		Total
	Ground Water	Surface Water	Ground Water	Surface Water		Ground Water	Surface Water	Ground Water	Surface Water	
25 - 500	4,636,537	613,040	2,292,331	86,703	**7,628,611**	29,219	1,440	16,981	460	**48,100**
501 - 3,300	14,276,857	5,641,249	2,504,229	220,499	**22,642,834**	9,735	1,674	2,571	146	**14,126**
3,301 - 10,000	14,466,791	10,769,268	308,157	93,422	**25,637,638**	2,347	994	57	12	**3,410**
Subtotal	**33,380,185**	**17,023,557**	**5,104,717**	**400,624**	**55,909,083**	**41,301**	**4,108**	**19,609**	**618**	**65,636**
Over 10,000	55,392,053	143,112,906	201,827	363,283	**199,070,069**	1,449	1,316	9	0	**2,774**
Total	**88,772,238**	**160,136,463**	**5,306,544**	**763,907**	**254,979,152**	**42,750**	**5,424**	**19,618**	618	**68,410**

The population and water system information used in this table is from the 1997 SDWIS database inventory. The information in this table was used to derive the sample distribution and statistical calculations found in other tables in this document. Information in this and other tables in this document are included as illustrations of UCMR Program design details and, as such, should *not* be interpreted as final program parameters. When the actual representative sample selection process is conducted, the most current population and water system data will be used. Note, therefore, that the final population and water system information will change based on the updated inventory.

serve less than 500 individuals, then 10 percent of the sample systems in that State should come from the PWSs in this size and source category. The distribution of systems across the State, therefore, is accommodated by the population-weighted statistical sample selection.

Therefore, the sample is stratified by system type (CWSs and NTNCWSs) and by source water type (ground water and surface water) within each small system size category (categories 1 through 3) in each State.

2.3 Tribal Water Systems as an Individual Stratum

Small PWSs that are located on Tribal lands in each of the ten EPA Regions will be grouped into a single category for the representative sample; this Tribal category is equivalent to a State for the statistical selection process. Tribal systems will have the same probability of being selected as other water systems in the stratified random selection process that weighs systems by water source and size class by population served. Using this discrete stratum ensures that the Tribal systems are selected as part of the national representative sample. The systems selected will comprise the "State Plan" for Tribal water systems.

2.4 Consistency of State Plans

EPA will select the representative sample from the population of CWSs and NTNCWSs nationally, then the sample will be allocated on a State-by-State basis, weighted approximately for the proportion of population served by each service size category and water source type. Based on a stratified random selection process applied to CWSs and NTNCWSs, the sample size is weighted by population served (to enable exposure assessments from Assessment Monitoring results) and water source type (to enable comparisons between surface or ground water) while allocated proportionately amongst States (to ensure geographic coverage) within service size category (categories 1 through 3). EPA will select two to three times as many CWSs and NTNCWSs as required for a national representative sample. These systems will appear on an "initial plan" list and a "replacement" list. The initial plan list of systems will identify those systems selected for each State.

States can include the EPA-selected systems on the initial plan list in their State Plan. If, however, the State Review determines that a system on the initial plan list has closed or merged, the system can be removed from the State Plan List. To remove a system from the State Plan List and replace it with another, the State must notify EPA of the reasons for removal. Valid reasons for removal include system closure, system merger, or a determination that a system operates exclusively with purchased water.[3] To identify a replacement system for the system removed, States will select the first water system (from the appropriate category) from the existing replacement list. (See Section 4 for a more detailed discussion of initial plan and replacement list selection procedures.)

When the list of systems is finalized, States will inform the EPA Regional Office of the States' choice of plans (including the details of any modified plans). As needed, the EPA Regional Office will work with the State to develop an acceptable modified plan. The State Plan will include a

[3] Purchased water systems may be required to monitor for UCMR microbiological contaminants that occur primarily in distribution lines.

process for the State to inform the systems of their selection as part of the representative sample and the systems' responsibilities related to their participation in the UCMR. This approach ensures a nationally consistent system selection process (whether a State accepts the initial plan list or generates a modified plan list of systems to sample) and enables acceptable plan development with minimal State burden.

If the EPA Regional Office does not receive the notice of a State Plan within 60 days, EPA will assume that systems on the initial plan represent the State Plan. The plan will also specify the timing of the monitoring. The State may adjust this time in the Plan to coordinate with compliance monitoring, if appropriate. States may also designate the most vulnerable period for sampling of systems in their jurisdiction. States will also be asked to nominate systems vulnerable to UCMR (1999) List 3 contaminants for Pre-Screen Testing, though this may be done in a separate request.

3. Selecting the Representative Sample for Systems Serving 10,000 or Fewer People

3.1 Determining the Size of the National Sample

The general population of small systems from which the representative sample will be drawn is found in Table 1. The data from the representative sample must be of high quality to estimate national occurrence and exposure, and to be dependable in guiding development of possible regulatory alternatives. In the UCMR, national occurrence is defined as the fraction of systems where a contaminant occurs, and exposure is defined as the fraction of the population exposed to a contaminant. Hence, the first step in designing the sample is to define the acceptable or allowable measurement error by setting precision and confidence levels. Two facets of the allowable measurement error are described below.

The first type of potential error describes the precision or tolerance. Precision reflects the understanding that the sample value may not precisely reflect the value for the population as a whole. EPA will use a one percent allowable error level, i.e., the (estimated) sample value will fall within one percent (above or below) the true value for the population as a whole. This allowable error is also known as the confidence interval.

The second type of error may be expressed using the confidence level. The confidence level describes the probability that the sample results will be within the range set by the precision figure. For example, EPA will use a confidence level of 99 percent, which suggests that 99 times out of 100, the (estimated) sample results will fall within one percent of the true population.

EPA has specified these stringent statistical parameters to ensure high quality data and dependable monitoring results. In general, many similar random surveys with continuous variables use a lower level of confidence (95 percent) and/or a larger allowable error (plus or minus 5 percent). However, use of a larger possible error is unacceptable for this program. Examination and analysis of current occurrence data shows that many contaminants that are currently regulated, or being considered for regulation, occur in one percent or less of systems on a *national* basis. However, for many contaminants, a one percent occurrence nationally reflects a substantially larger occurrence regionally. Even a small percentage of systems with detections of a contaminant can translate into exposure of a significant population. By accepting a greater margin of error, and the resultant smaller sample size, such small national occurrence might be missed entirely.

EPA must also have the capability to evaluate contaminant occurrence in relation to source waters and different size categories of systems. Many statutes and current regulations are implemented differently for systems of different size, or for different source water categories. Combining the representative (small system) sample with the results from all large systems provides increased power in the total sample, but EPA must also be able to evaluate occurrence, and possible regulatory options, related to the small systems themselves. SDWA and many current rules focus on burden reduction for small systems when feasible.

There are also other uncertainties and sources of variance in such a sample program. For example, all contaminants have censored distributions (i.e., "less than the detection level" analytical results) and there are a myriad of factors that affect variability and vulnerability of ground water systems. It is not clear how normal sampling theory accommodates some of these sources of variation. Hence, the high confidence level, low allowable error, and larger sample size should help to ensure adequate data to meet the objectives of the UCMR Program.

To define the sample size required to meet the values for allowable error and confidence level, the occurrence and variability within the population must also be accounted for. The variance is, of course, unknown before the survey is conducted, but it can be estimated within various bounds. In the following discussion, p will represent the true proportion of systems with contaminants, and 1 - p is the true proportion of systems without any contaminants.

Given a population with the true proportion of systems with contaminants assumed as p, the sample size (n) required to produce the specified confidence level and allowable error (d) estimate of the population mean is,[4]

$$n = \frac{z^2 * p(1-p)}{d^2} \qquad (1).$$

Here z is the critical value at 99 percent confidence, taken from the table of the normal distribution. The underlying assumptions of the approximation used to derive equation (1) are: (1) that we take a simple random sample from the population of systems; (2) that the sample is large enough for a normal approximation to hold; and (3) that in each system we can determine with certainty whether or not a contaminant is present. These assumptions are only approximately correct, so the sample size calculation is also only approximately correct. The more complicated stratified sampling plan, as opposed to the simple random sampling plan assumed here, is taken into account when confidence intervals are calculated in Section 7.

The largest value of the product $p(1 - p)$ is 0.25 occurring when $p = 0.5$. In other words, without precise data on each system, the most conservative assumption least likely to underestimate the potential error is to use an estimate of 50 percent variability ($p = 0.5$). This results in the largest value for n (with other factors held constant). However, analysis of regulated and prior unregulated

[4] The normal approximation to the binomial distribution was used. For rare events (e.g., one percent occurrence) the Poisson distribution may provide a better approximation. However, as sample size increases the differences diminish. The sample size estimated for the UCMR is great enough that there is no substantive difference in the estimated n.

contaminant monitoring occurrence results indicate that only a very small proportion of systems on a national level are likely to exhibit any contaminant occurrence. Hence an estimate of 1% occurrence, or $p = 0.01$, was selected. This assumption is believed to be appropriate and accurate while balancing cost and logistical considerations with sample size.

Given the standard normal distribution, the critical value for z at the 99 percent confidence level is 2.58. The one percent margin of error (d=0.01) suggests:

$$\text{sample fraction} - .01 < \text{population fraction} < \text{sample fraction} + .01$$

The necessary sample size is then calculated as:

$$n = \frac{(2.58)^2}{(0.01)^2} * (0.01 * 0.99) = 658.98 \cong 659 \qquad (2).$$

Thus, for the population of 65,636 small systems, a representative sample size of approximately 659 systems will provide a confidence level of 99 percent with an allowable margin of error of ± 1 percent. However, to provide for a broad geographic coverage, a portion of the sample needs to be distributed among all States. EPA will specify the stratified sample process so as to ensure a minimum of two representative systems allocated to each State. It is important that all States, and at least several systems in each State, contribute to UCMR occurrence results. These results will be proportionate to the population served by PWSs within each system size category and by water source type (surface or ground water). Contaminant occurrence results will be proportionate to population served to enable EPA decision making based on exposure assessments.

Given the potential small individual State sample size, no statistically valid conclusions may be drawn at the State level. However, EPA still considers it important that all States are represented and have the opportunity to participate in the UCMR State Plan. Some contaminants, such as some pesticides, may only be used intensively in specific regions of the country. It is possible that with the relatively small number of systems in the representative sample, monitoring may miss contaminants with such targeted regional use patterns. However, including systems in every state in proportion to the population served should ensure that contaminants with regional use patterns, to the extent that they potentially contaminate water supplies, are proportionately represented by the national sampling design. These factors were also considered in selecting the number of systems for the national representative sample.

EPA proposes to use a sample size of 721 CWSs and 79 NTNCWSs for a total of 800 small systems for the representative sample. This sample size was selected for various statistical and budgetary considerations. A sample size of 721 CWSs is more than the minimum 659 CWSs needed to ensure a 99 percent confidence level, (see Equation 2 above) and allows sampling of at least two CWSs in each State. The number of NTNCWSs selected for inclusion in the sample reflects the proportion of the NTNCWSs, and the proportion of the population served by NTNCWSs.

Table 2 illustrates the composition of the nationally representative sample of 800 systems by system size and type (CWSs vs. NTNCWSs and ground water vs. surface water). In order to gather more information about the systems in the very small category of CWSs (Category 1) and improve the statistical power of results in this category, the number of very small ground water systems was increased by 6, and the number of very small surface water systems was increased by 56, compared to an allocation that would be strictly proportional to the population served by these systems. Due

to the small sample size of the NTNCWSs in the ground water and surface water categories within each size category (Categories 1 through 3), statistical conclusions about NTNCWSs must be analyzed with caution. Conclusions about NTNCWSs cannot be based on source water type since the margin of error would be too great.

Table 2. Population-Weighted National Representative Sample Distributed by System Size Category and Water Source Type

Size Category (by population served)		Number of CWSs		Number of NTNCWSs		Subtotal of All Systems by Water Source Type		Total
		Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	
Category 1	500 and Under	67	64	33	2	100	66	166
Category 2	501 to 3,000	186	74	36	3	222	77	299
Category 3	3,001 to 10,000	189	141	4	1	193	142	335
Total		**442**	**279**	**73**	**6**	**515**	**285**	**800**

CWS = Community Water Systems, NTNCWS = Non-Transient Non-Community Water Systems

Note: The population-weighted distribution of samples indicated above is based on population and water system information from the 1997 SDWIS database inventory. The table above provides an illustration of the anticipated approximate distribution of water systems selected for the national sample as based on population served by system size category, water source type, and water system type. When the actual representative sample selection process is conducted, the most current population data will be used. The actual, final distribution of the number of systems by category will change based on the updated population inventory, but the total sample number of 800 systems will remain unchanged.

3.2 Selecting a Representative Sample of Systems in Individual States

Given the UCMR Program's requisite 99 percent confidence level (± 1 percent margin of error) and the other considerations discussed, the total number of systems in the representative sample (800) is then allocated approximately in proportion to the population served, by source water type and equally across States, Territories, and Tribes, by three system size categories (Table 2). Approximately 62 extra systems were added to Category 1 to increase statistical power, therefore the sample is not strictly allocated by the proportion of the population served. In each State, the total number of systems is allocated in proportion to the population served in the State. For example, presume in State Y, 156,718 individuals are served by ground-water supplied CWSs in category 1. The number of individuals served nationally in this size category is estimated as 4,636,537 (Table 1). The number of systems in this category in the national sample is 66. Therefore, in category 1, the number of ground-water CWSs required in the representative sample, x, in State Y is calculated as:

$$x=\frac{156{,}718}{4{,}636{,}537}*66=2.23\cong 2 \quad (3).$$

The number of systems in each State will be rounded so that the total number of systems in the survey equals 800, and so that no State is represented by less than 2 systems. The procedure is repeated for all system size and source water type categories to estimate the total number of systems in each State.

4. Selecting Systems for Initial Plan List and the Replacement List in Each State

EPA will choose the PWSs for the national sample through a stratified random selection process. For each system size category, stratified by system type (CWSs and NTNCWSs) and source water supply (surface or ground water), EPA will: (1) list and systematically assign a number to each of the systems within these groups for each State/Tribe; and (2) generate a random sequence of uniform integers between one and the total number of systems in that class, using a uniform random number generator.

The initial plan list includes the actual number of samples initially allocated to a State through the statistical random selection process. The replacement list is a list of systems comprised of additional randomly-selected systems that may be used to replace systems on the initial plan list if necessary. Replacement of a system on the initial plan list may occur only when the initial plan list system has closed, merged, or is identified as purchasing all of its water supply. Note that in the case of microbiological sampling, purchased water systems may remain on the initial plan list. EPA will develop guidance on the use of purchased water systems in conjunction with guidance on monitoring for UCMR (1999) List 2 and UCMR (1999) List 3 contaminants.

To illustrate system selection, we can continue with the example from Equation 3. State Y has 494 ground-water supplied small CWSs in Category 1. The 494 systems are listed in order by PWSID and are numbered from 1 to 494. According to the proportion of population in State Y served by this system-size category and type, two systems will be selected for UCMR monitoring from this group (Equation 3). EPA will randomly select two to three times this required number of systems to provide a replacement list for each size category for each State. The random number generator provides a list of six numbers: 26, 294, 48, 137, 303, and 2 (with the numbers corresponding to PWSID numbers). Hence, systems number 26 and 294 (i.e., the first two system numbers randomly selected that fit the required size and type categories) will be the two systems selected for State Y's national representative sample initial plan list. The four additional systems randomly selected (i.e., systems numbered 48, 137, 303, and 2) will be placed on State Y's replacement list.

5. Selecting Systems for the State Plan

Each State, tribe and territory will have 60 days to review the initial plan list. The State/Tribe will either: (1) accept the selections as its State Plan and notify the Regional Administrator of its acceptance along with its procedure to inform the selected systems of their responsibilities for monitoring; or (2) propose deletions from the initial plan list and select alternates from the replacement list as its State Plan, including the reasons for the changes, informing the Regional

Administrator of the proposed changes; or (3) take no action within 60 days, allowing the Regional Administrator to specify the portion of the representative sample applicable to the State as its State Plan. In the second case, the Regional Administrator will have 60 days to work with the State to develop a suitable plan, if problems are encountered. (For further information on specific guidance on developing State Plans, please refer to EPA's *Unregulated Contaminant Monitoring Regulation: Implementation Guidance for States*.)

Any system(s) removed from the initial plan list must be replaced by the system(s) selected next in sequence on the replacement list, as they are ordered by random selection. Continuing with our example in State Y, systems 26 and 294 were randomly selected as State Y's two representative systems (again, according to the required size and water type categories) to be included on the State's initial plan list. However, State Y verifies that system 26 was taken out of service within the previous year. The State then chooses the first system on the replacement list, in this example, system number 48, to replace system number 26. The modified State Plan list is then comprised of systems 48 and 294. If system 294 was also not suitable, system 137 (next in the replacement sequence) would become its replacement; if 137 was not suitable, then system 303 would become the replacement, and so forth.

In summary, each State/Tribe reviews its portion of the national representative sample to determine that the systems selected have the appropriate operational status. The State/Tribe submits its representative sample listing to the EPA Regional Office, with all changes from the initial list marked and the reasons for any changes noted. This list is included in the State Plan, and becomes a portion of the national representative sample.

States/Tribes may also sample additional systems. However, any additional sites sampled by States would not be combined with those of the representative sample for the purpose of computing national estimates of contamination. EPA cannot pay for the testing of these additional systems. These additional systems, though providing useful information, will bias the national set of systems if included with those selected using the stated national criteria. However, if the States provide the results of such monitoring, EPA will receive the data through SDWIS for input to the National Drinking Water Contaminant Occurrence Database (NCOD).

6. Index System Monitoring

EPA will identify up to 30 systems from the representative sample to be "Index" systems. The data collected from the Index systems will be used partly for added quality control and to better characterize monitoring results and operating characteristics of small systems. These systems will be monitored every year for five years (one complete UCMR cycle). This will provide some detailed information regarding temporal variations during the course of the UCMR monitoring, as well as possible effects related to operational changes. EPA will pay for this monitoring, including provisions for sampling equipment, labor for sample collection, shipment of samples, testing and analysis. Additional water quality and operational data from these systems will also be collected at the same time, with minimal burden to the systems. The Index systems will be selected in proportion to the population served in each size category and water source type. Among each system size category and source water type, systems will be chosen randomly from the national representative sample used for Assessment Monitoring. Table 3 illustrates the number of systems chosen in each size category as Index systems from the representative sample.

Table 3. Distribution of Index Systems in the Representative Sample

Size Category	Number of Non-Index Systems	Number of Index Systems
Ground Water		
500 and Under	96	4
501 to 3,000	213	9
3,001 to 10,000	185	8
Surface Water		
500 and Under	66	0
501 to 3,000	74	3
3,001 to 10,000	136	6
Number of Systems in the Representative Sample	**770**	**30**

Note: The distribution of samples indicated above is based on the 1997 SDWIS database inventory. The table above provides an illustration of the anticipated approximate distribution of sample systems based on population served by system size category. When the actual representative sample selection process is conducted, the most current population data will be used. The actual, final distribution of the number of systems by population size category will change based on the updated population inventory, but the total sample numbers by system type (non-index vs index), as illustrated above, will remain unchanged.

7. Assessment Monitoring

The UCMR requires all 2,774 large and 800 small CWSs and NTNCWSs (the national representative sample) to monitor for the contaminants for which established analytical methods are available. This first stage of the UCMR is called Assessment Monitoring and includes twelve organic chemicals (listed in §141.40(a)(3) Table 1, UCMR (1999) List 1) for monitoring. EPA plans to have one-third of the representative sample (267 systems) monitor in each of the three Assessment Monitoring years (2001 to 2003). This distribution of sampling effort is designed to facilitate laboratory scheduling and other logistical considerations. The small systems will be delegated to a sampling year by random selection with a 33 percent probability that each system will be selected in each of the three years. As stated earlier, Assessment Monitoring is being conducted to assess exposure to contaminants, as well as contaminant occurrence. An exposure assessment estimates the fraction of the population that is exposed to a given contaminant, while contaminant occurrence estimates the fraction of systems in which a contaminant occurs.

After the sampling year is selected, each system will be assigned specific weeks during the year when their samples will be collected, with four sampling times per year for surface water systems and two per year for ground water systems. One sampling period must be during the most vulnerable period, as designated in the regulation. The specification of year-month-week will not

only facilitate scheduling of laboratory resources, but will ensure that sampling covers vulnerable periods and all seasons to assess some aspects of temporal occurrence patterns. To provide States with flexibility in determining vulnerable periods, EPA is allowing the vulnerable period samples to be taken within 2 weeks (plus or minus 2 weeks) of the scheduled sampling date. EPA is also allowing the second ground water sample to be taken within 5 to 7 months of the initial vulnerable period sample. While Index systems sample during all five years of the UCMR cycle, each Index System will also be assigned an "official" sample year. Only the data from the official sample year will be used in the national summary of results from the Assessment Monitoring, for consistency with the sample design.

The UCMR cannot specify any particular year for Assessment Monitoring for the large PWSs, but does specify that they must conduct their monitoring within the first three years (2001-2003) of the UCMR cycle. EPA expects that large system UCMR monitoring for unregulated contaminants coincide, whenever possible, with required monitoring for regulated contaminants. Since monitoring schedules for regulated chemicals depend on system size and detection history, compliance schedules vary significantly. EPA recognizes that although it will be desirable to collect UCMR samples concurrently with compliance samples for regulated chemical contaminants, sometimes it may be difficult to coordinate the two sampling events. Large systems are required to bear the costs of sampling, testing and reporting the results, and coincident monitoring will help reduce the burden.

Since all the systems in the representative sample (i.e., 800) will be required to conduct Assessment Monitoring, the allocation of systems follows the example given in Equation 3. More generally, the number of systems conducting Assessment Monitoring (A_{ni}) in category n in State/Tribe i, is calculated as:

$$A_{ni} = \frac{P_{ni}}{NP_n} * Y_n \qquad (4).$$

Where P_{ni} is the population served by system category n in State/Tribe i, and NP_n is the total national population served by systems in this category, Y_n is the number of systems allocated to category n.

Table 4 illustrates the total number of CWSs conducting Assessment Monitoring, the sample number (n) distribution according to system size, and the associated margins of error at 99 percent and 95 percent confidence levels. Note that Table 4 does not include data for NTNCWSs. Given the small number of samples allocated to the NTNCWSs (79), statistical inferences specific to this system-type category can not be made under the necessary confidence levels and margins of error. Also, there is a potential overlap between the populations served by CWSs and NTNCWSs. Therefore, given the possibility of potential double-counting of populations served and the related complexities of appropriately estimating population exposure to identified contaminants, the monitoring results for the NTNCWSs will not be combined with the CWSs' for national exposure estimates. However, the monitoring results for the NTNCWSs will, nonetheless, provide important qualitative contaminant occurrence information for populations served by those systems and in preliminary comparisons to CWSs' monitoring results.

The information in Table 4 indicates that results from Assessment Monitoring of representative sample systems can be extrapolated for national occurrence and exposure estimates within reasonable confidence levels (99 or 95 percent) and margins of error (±1 to ±2 percent) for: (1) all small CWSs, and (2) all ground water- and surface water-supplied systems. However, within each

size category, the sample size can be as low as 64 systems, raising the margin of error of estimation slightly (to ±3 percent) for some subcategories of the sample. As noted elsewhere, results can not be used to estimate occurrence at the State level.

The error ranges in Table 4 are computed by the statistical formulas in Appendix A, using the normal approximation shown in Equation (1). This approximation is valid when n and p are large enough. For example, Casella and Berger (1990) recommend $n^*p \geq 5$, while Parzen (1960) recommends $n^*p \geq 10$. In Table 4, where $n = 721$ and $p = 0.01$, $n^* p = 7.21$. By this measure, the normal approximation may not be valid. However there is a clear problem with the normal approximation in Table 4: some of the error bounds are so wide that they include negative occurrence fractions within the margin of error. For example, among very small surface water systems, when the observed fraction of systems with a contaminant is 1 percent, a 95 percent confidence interval for the true fraction is 0.01 ± 0.02, or [−0.01, 0.03]. This interval allows the possibility of a negative fraction of occurrence, which cannot logically occur. The interval may be truncated to [0, 0.03], but the need to truncate suggests that the normal approximation is not the most appropriate method to calculate the actual confidence level and margin of error.

Table 4. Allocation of CWSs Conducting Assessment Monitoring with the Associated Margins of Error for an Estimated Exposure of 1%

Size Category	Ground Water-Supplied Systems			Surface Water-Supplied Systems			Total		
	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]
500 and Under	67	±3	±2	64	±3	±2	131	±3	±2
501 to 3,300	186	±2	±1	74	±3	±2	260	±2	±1
3,301 to 10,000	189	±2	±1	141	±2	±2	330	±1	±1
Total	**442**	**±1**	**±1**	**279**	**±2**	**±1**	**721**	**±1**	**±1**

[1] Values in the columns with the heading of "n" indicate the number of CWSs allocated to a specific system size category.

[2] These column headings indicate the confidence level used for evaluation. The values preceded by "±" listed in these columns are the margins of error associated with the designated confidence level (either 99 percent or 95 percent). Error calculations in the table are based on an estimated occurrence fraction of $p = 0.01$.

The distribution of samples across the three size categories in Table 4 is approximately proportional to population served by each of the respective community water system size categories. An extra 62 systems were allocated to the smallest system size category to increase the statistical power of the sample, by decreasing the margin of error. The population figures used to determine this distribution are based on data from the 1997 SDWIS database inventory. The sample distribution, confidence levels, and margins of error included in this table are intended only to illustrate the UCMR Program design details and, therefore, are not final program parameters. When the actual representative sample selection process is conducted, the most current population data will be used and the related, final program sample distribution, confidence levels, and margins of error will be calculated. Note that the total sample size indicated above will remain unchanged in the final program design.

See Appendix A for details on how to calculate the normal and Wilson score confidence intervals.

The normal-based confidence interval is only one of several possible confidence intervals for an estimated proportion. Newcombe (1998) compares seven such intervals, including two varieties of

the normal interval. Of these, the Wilson score interval without continuity correction (Wilson, 1927) has good statistical properties (e.g., the stated confidence level is approximately correct for a wide range of n and p), is simple to compute, and unlike the normal interval, always gives confidence limits between 0 and 1. Given an estimated occurrence fraction p from a sample of size n, the Wilson score interval for p is computed as:

$$\frac{2np + z^2 \pm z\sqrt{z^2 + 4np(1-p)}}{2(n + z^2)} \quad (5).$$

where z is the critical value of the normal distribution at the desired confidence level. Returning to the example of very small surface water systems, for an estimated occurrence fraction of p=0.01 from a sample of size n=64, a 95 percent Wilson score interval for the true proportion is:

$$\frac{2(64)(0.01) + (1.96)^2 \pm 1.96\sqrt{(1.96)^2 + 4(64)(0.01)(0.99)}}{2(64 + (1.96)^2)} = [0.0013, 0.0742] \quad (6).$$

So with 95 percent confidence, the true proportion lies somewhere between 0.1 percent and 7.4 percent. By comparison, the normal interval for this example was −1 percent to +3 percent. Although the Wilson interval in this example is wider than the normal interval, it is more believable in part because it does not include negative occurrence values.

Table 5 compares the Wilson and normal confidence intervals, still assuming an estimated occurrence fraction of p=0.01 and using the sample sizes given in Table 4. A simple interpretation of these intervals is that the normal interval equals p, the estimated fraction, plus or minus some amount, while the Wilson interval equals p times or divided by some amount.

In summary, the normal-based error ranges in Table 4 are useful as a rough guide to the expected precision of an estimated occurrence fraction. Moreover the normal approximation yields the simple formula in Equation (1) for estimating the sample size needed to achieve a given precision with given confidence. However when computing confidence intervals for the estimated proportion, the Wilson score interval is preferred, both because of its good statistical properties and because it avoids the possibility of including negative occurrence values.

8. Screening Surveys

The second monitoring component of the UCMR is called the Screening Survey. A second group of contaminants will be monitored in the Screening Surveys. This group of contaminants includes thirteen organic contaminants, one microbiological contaminant, and one radiological contaminant for which methods are currently being refined. These contaminants are listed in §141.40(a)(3) Table 1, UCMR (1999) List 2. Analytical methods for these contaminants are in development, but are not ready for wide-scale, general use. When further developed and ready for use, these methods will need to be used initially under close quality-controlled conditions. Therefore, a designated group

of EPA-certified laboratories will be used for screening survey analytical methods to ensure data quality of the new methods. With these concerns, the Screening Surveys will be conducted through a small subset of systems monitoring under the UCMR to provide a national screening for the UCMR (1999) List 2 contaminants and to better establish the analytical methods used.

Table 5. Comparison of Confidence Intervals at the 99 Percent Confidence Level for CWSs

Size Category	Wilson Score Confidence Intervals		
	Ground Water-Supplied Systems	Surface Water-Supplied Systems	All
500 and under	[0.001, 0.108]	[0.001, 0.108]	[0.001, 0.091]
501 to 3,300	[0.002, 0.052]	[0.001, 0.100]	[0.002, 0.042]
3,301 to 10,000	[0.002, 0.052]	[0.002, 0.063]	[0.003, 0.037]
Total	[0.003, 0.031]	[0.002, 0.046]	[0.004, 0.026]

Size Category	Normal Confidence Intervals		
	Ground Water-Supplied Systems	Surface Water-Supplied Systems	All
500 and under	[-0.021, 0.041]	[-0.021, 0.041]	[-0.018, 0.038]
501 to 3,300	[-0.009, 0.029]	[-0.019, 0.039]	[-0.006, 0.026]
3,301 to 10,000	[-0.008, 0.028]	[-0.010, 0.030]	[-0.003, 0.023]
Total	[-0.002, 0.022]	[-0.006, 0.026]	[0.000, 0.020]

Each matrix above represents the confidence intervals using both the Wilson Score method and the normal distribution method. The confidence level in each matrix (i.e., for ground water-supplied systems serving 500 and under) is specified as 99 percent.

The Screening Surveys are being conducted to assess contaminant occurrence in PWSs, and not to determine exposure assessment by population (as is the purpose of Assessment Monitoring). EPA estimates that there will be two different groups of systems involved in the Screening Surveys. Each group will be comprised of 300 large and small CWSs and NTNCWSs. The first group will conduct the Screening Survey in the year 2001 or 2002, the second group will conduct the Screening Survey in 2003. The two groups will monitor for different contaminants based on the estimated timing of when methods will be available. Sampling schedules have been established, in part, to enable Screening Survey water sample collection coincident with the Assessment Monitoring sample collection whenever possible to minimize labor burden for sample collection.

EPA is examining general thresholds to evaluate Screening Survey results, relative to the margin of error in the sample. For example, if a contaminant occurs over a certain threshold (i.e., in a percentage of systems/population served), the contaminant may then be placed on the Assessment Monitoring list and monitored in the next round of the UCMR by all large systems and a representative sample of small systems. If the contaminant occurrence is below this threshold, it is possible that no further testing will be required. Factors such as health effects levels will also need to be considered; hence, thresholds may vary by contaminant.

Both large and small systems will be included in the Screening Surveys. Systems will be selected from all the size and water source categories. However, selection will not be proportionately weighted by the population served, or by the proportion of system size category. If the sample is weighted by population served, a disproportionate number of large systems would be included in the Screening Surveys. However, if the sample is weighted by the number of systems in each size category, a disproportionate number of small systems would be represented. Therefore, each size category is given equal importance with 60 systems selected from each size category, with the selected systems distributed proportionately between surface water and ground water systems. This results in 180 small systems and 120 large systems in each of the Screening Surveys (i.e., a total of 360 small systems and 240 large systems in the two Screening Surveys). To make national population estimates, or system estimates, the resultant data will need to be weighted in relation to these sample distributions.

Table 6 illustrates the allocation of systems in each size category in each group for each Screening Survey and the associated margin of errors of estimation at the 99 and 95 percent confidence levels to evaluate the measurement precision for the sample of 300 systems. Even though there are a total of 600 systems involved, there will be, as noted, two Screening Surveys performed, by two mutually exclusive groups of systems, analyzing water samples for two different sets of contaminants.

Table 6. Allocation of Systems for Screening Surveys by Size Category with the Associated Confidence Levels and Margins of Error

Size Category	Ground Water-Supplied Systems			Surface Water-Supplied Systems			Total		
	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]
500 and Under	54	±3	±3	6	±10	±8	60	±3	±2.5
501 to 3,300	44	±4	±3	16	±6	±5	60	±3	±2.5
3,301 to 10,000	35	±4	±3	25	±5	±4	60	±3	±2.5
Subtotal Small Systems	**133**	**±2.2**	**±1.7**	**47**	**±3.7**	**±2.8**	**180**	**±1.9**	**±1.5**
10,001 to 50,000	51	±4	±3	9	±9	±7	60	±3	±2.5
50,001 and over	20	±6	±4	40	±4	±3	60	±3	±2.5
Subtotal Large Systems	**71**	**±3.0**	**±2.3**	**49**	**±3.7**	**±2.8**	**120**	**±2.3**	**±1.8**

Size Category	Ground Water-Supplied Systems			Surface Water-Supplied Systems			Total		
	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]	n [1]	99% [2]	95% [2]
Total	**204**	**±1.8**	**±1.4**	**96**	**±2.6**	**±2.0**	**300**	**±1.5**	**±1.1**

1 Values in the columns with the heading of "n" indicate the number of CWSs allocated to a specific system size category.

2 These column headings indicate the confidence level used for evaluation. The values preceded by "±" listed in these columns are the margins of error associated with the designated confidence level (either 99 percent or 95 percent). Error calculations in the table are based on an estimated occurrence fraction of $p = 0.01$.

Monitoring results for Screening Surveys must be analyzed and interpreted with careful consideration to appropriate population-weighting. Since the number of systems within each size category in this sample is equal (60 systems), the monitoring results must be weighted by population within each service size category before interpretation.

The distribution of samples across all categories in Table 6 is proportional to the respective population served. The population and water system information used to determine this distribution are based on data from the 1997 SDWIS database inventory. The sample distribution, confidence levels, and margins of error included in this table are intended only to illustrate the UCMR Program design details and, therefore, are not final program parameters. When the actual representative sample selection process is conducted, the most current population data will be used and the related, final program sample distribution, confidence levels, and margins of error will be calculated. Note that the total sample sizes indicated above will remain unchanged in the final program design.

Results from the Screening Surveys are likely only suitable for aggregate national estimates given the 99 percent confidence level and ± 1.5 percent margin of error. Only aggregated national estimates are appropriate because the error margin may be too large in small subcategories (e.g., surface or ground water systems in a given size category) to be conclusive, particularly in cases where no detections occur. For example, a contaminant most likely to occur in small surface water systems could have a zero occurrence in the sample, but this contaminant might actually occur in up to 3.5 percent of these surface water systems nationally. Note also that since the total number of systems allocated to each size category is equal (60 systems per category), the monitoring results will have to be weighted by the proportion of the population within each service size category. Monitoring results will have to be carefully analyzed to correctly assess the possible implications of such results.

To implement the Screening Surveys, EPA will select 180 small PWSs from the set of 267 systems (i.e., one-third of the 800 systems in the national representative sample), scheduled to conduct Assessment Monitoring either in year 2001 or 2002 (for the first group) and again in year 2003 (for the second group). The probability of a system being selected for Assessment Monitoring (A) in any given year n, is 267/800, or $P_n(A) = 33$ percent. Given that a system is first selected for Assessment Monitoring (A) in any given year n, the probability of that system also being selected for Screening Survey (S), is:

$$P_n(S|A) = \left(\frac{180}{267}\right) = 0.67 \qquad (7).$$

Overall, there is a 22.5 percent probability that a system will be selected for both the Screening Surveys and Assessment Monitoring in the same year (67 percent chance of being selected for Screening Surveys multiplied by a 33 percent chance of being selected for Assessment Monitoring). However, if the first Screening Survey is conducted in the year 2002, the systems selected to conduct Assessment Monitoring in the year 2001 have no chance of being selected for a Screening Survey. Overall, there is a 45 percent chance for a small system to be selected for both Assessment Monitoring and a Screening Survey simultaneously. Therefore, the probability of a system being selected only for Assessment Monitoring is estimated as 55 percent. Figure 2 depicts the number of systems and the probability of a system being chosen for Assessment Monitoring and a Screening Survey.

Similarly, for the large CWSs and NTNCWSs, the probability of a system being required to participate in a Screening Survey (S) is:

$$P_{large}(S) \equiv \left(\frac{240}{2774}\right) = 0.0865 \qquad (8).$$

Therefore, there is approximately a 9 percent probability that a large system will be chosen for a Screening Survey.

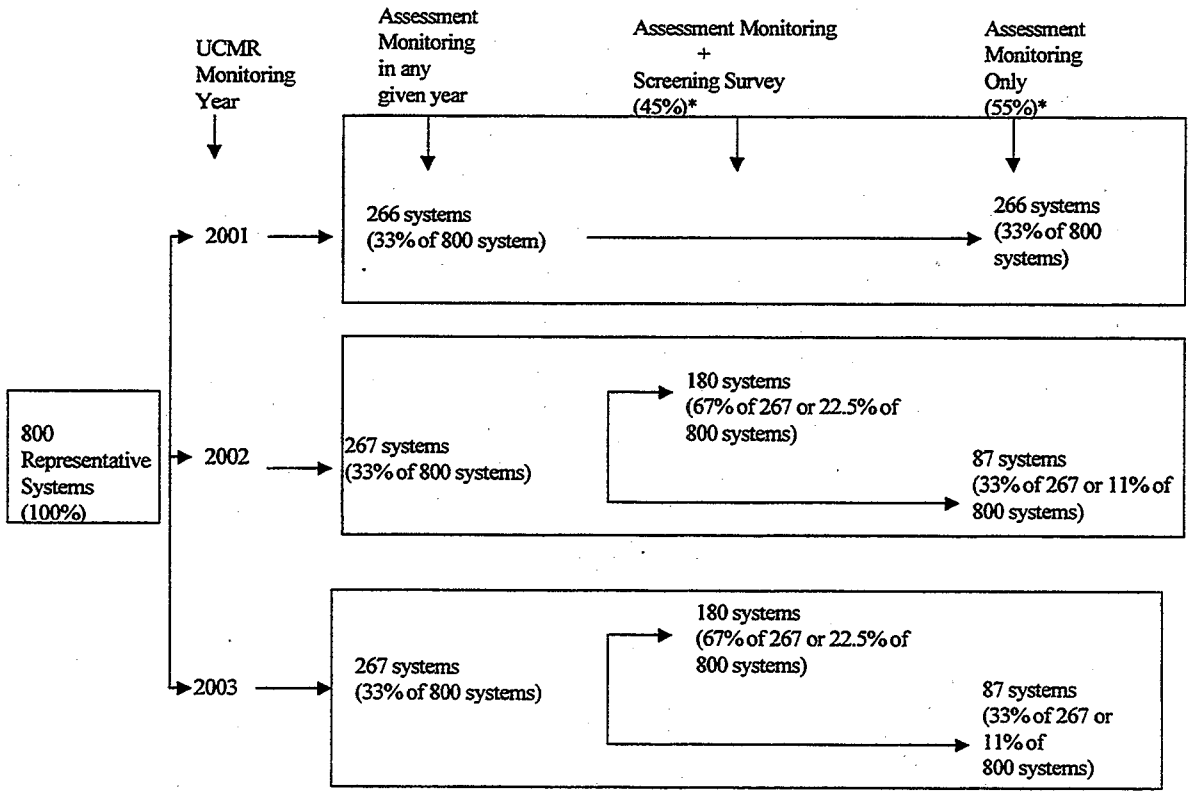
Again, based on the proportion of population served by small CWSs and NTNCWSs in each State, the number of systems selected for the two groups of Screening Surveys (S_n) in each State/Tribe n, is calculated as:

$$S_{ni} = \frac{P_{ni}}{NP_i} * Z_i \qquad (9).$$

where P_{ni} is the population served by small systems in State/Tribe n in category i, and NP_i is the total national population served in system category i, and Z_i is the total number of systems required to conduct the survey in that category i.

Table 7 illustrates the allocation of systems conducting Assessment Monitoring and Screening Surveys in each State/Tribe based on the population served by the systems. The allocation of PWSs in Table 7 is based on the January 1997 inventory estimates from the SDWIS database. The actual allocation of samples within States, Tribes, and Territories may change when the represented State sample is selected from current inventory numbers.

Figure 2. Number and Probability of Small Systems Chosen for Assessment Monitoring and Screening Surveys for the UCMR Years



* Overall Probability (over three years)

Table 7. Distribution of Small Systems Required to Conduct Assessment Monitoring and Screening Survey in Each State/Tribe/Territory

State/Tribes/ Territories	Population Served by Small Systems (10,000 or less people)[1] (P_n)	Number of Small Systems Conducting Assessment Monitoring,[2] (A_n)	Number of Small Systems Conducting Screening Surveys,[3] (S_n)
Tribes[4]	406,922	6	3
U.S. Territory[5]	664,719	10	4
Alaska	273,699	4	2
Alabama	1,437,985	21	9
Arkansas	1,067,162	15	7
Arizona	706,010	10	5
California	2,994,866	43	19
Colorado	632,197	9	4
Connecticut	425,457	6	3
Washington DC[6]	0	0	0
Delaware	139,300	2	1
Florida	2,086,859	30	13
Georgia	1,277,566	18	8
Hawaii	210,684	3	1
Iowa	1,089,434	16	7
Idaho	449,557	6	3
Illinois	2,463,266	35	16
Indiana	1,370,421	20	9
Kansas	820,989	12	5
Kentucky	1,193,681	17	8
Louisiana	1,655,137	24	11
Massachusetts	831,358	12	5
Maryland	510,175	7	3
Maine	337,773	5	2
Michigan	1,842,695	26	12
Minnesota	983,999	14	6
Missouri	1,405,886	20	9
Mississippi	1,741,105	25	11
Montana	354,745	5	2

State/Tribes/ Territories	Population Served by Small Systems (10,000 or less people)[1] (P_n)	Number of Small Systems Conducting Assessment Monitoring,[2] (A_n)	Number of Small Systems Conducting Screening Surveys,[3] (S_n)
North Carolina	1,688,147	24	11
North Dakota	234,434	3	2
Nebraska	468,742	7	3
New Hampshire	361,738	5	2
New Jersey	1,118,886	16	7
New Mexico	473,735	7	3
Nevada	261,755	4	2
New York	2,377,365	34	15
Ohio	1,967,750	28	13
Oklahoma	1,195,980	17	8
Oregon	653,761	9	4
Pennsylvania	2,452,599	35	16
Rhode Island	114,592	2	1
South Carolina	841,608	12	5
South Dakota	314,992	5	2
Tennessee	1,235,268	18	8
Texas	5,362,371	77	35
Utah	515,146	7	3
Virginia	1,131,704	16	7
Vermont	281,185	4	2
Washington	1,242,213	18	8
Wisconsin	1,265,579	18	8
West Virginia	781,716	11	5
Wyoming	194,170	3	1
Total	**55,909,083**	**800**	**360**

[1] The distribution of samples above is based on the population and water system information in the 1997 SDWIS database inventory. The sample distributions and populations included in this table are intended only to illustrate the UCMR Program design details and, therefore, are not final program parameters. When the actual representative sample selection process is conducted, the most current population and water system data will be used, and the related, final program sample distribution will be calculated. Note that the total numbers of systems conducting sampling indicated above will remain unchanged in the final program design.

[2] This column represents the total number of small systems allocated in individual State/Tribe from the national representative sample of 800 systems.

[3] There are 360 small systems shown for Screening Surveys; 180 for each of the two Screening Survey groups. Note that each Screening Survey Group of 120 large systems will also be required to monitor. Therefore, there is a total of 300 small and large systems (a total of 600 Screening Survey systems) in each Survey.

[4] The number of Tribal water systems includes Tribal systems in each of the 10 EPA Regions. Tribal systems were aggregated as a State to ensure that Tribal systems were represented in the national representative sample of small systems in the UCMR.

[5] U.S. Territories include American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the Virgin Islands. Territories were aggregated as a State to ensure that Territories were represented in the national representative sample of small systems in the UCMR.

[6] The Washington DC water supply is provided exclusively by large PWSs.

9. Pre-Screen Testing

The third monitoring component of the UCMR is Pre-Screen Testing. EPA established this third tier of the UCMR monitoring with its stakeholders for contaminants of concern for which analytical methods are in the early stages of development and/or whose methods are currently too expensive for wide-scale monitoring. Pre-Screen Testing may also address contaminants that have recently emerged or been identified as a concern, such as through the Governors' petition process. The purpose of this monitoring component will be to determine whether the methods in early development will provide adequate analytical results in conditions under which the contaminants are most likely to occur. Currently, there are seven microbiological contaminants and one radiological contaminant listed in §141.40(a)(3) Table 1, UCMR (1999) List 3 that are candidates for Pre-Screen Testing in 2004.

EPA will ask each State who has entered into a MOA with the appropriate EPA Region to identify a list of between 5 and 25 systems that might be most vulnerable to the UCMR (1999) List 3 Pre-Screen Testing contaminants. EPA will identify the number of systems selected to monitor in each State based on the population served by CWSs and NTNCWSs in the State. From this list, EPA will randomly select up to 200 large and small CWSs and NTNCWSs nationally for Pre-Screen Testing of the specified contaminants. The systems selected for Pre-Screen Testing will be added to the State Plans. The Pre-Screen Testing will use analytical results from a small sample to evaluate and improve methods, and to conduct an initial assessment of occurrence. Given the small number of Pre-Screen Testing systems, the monitoring results cannot be used to estimate national occurrence of UCMR (1999) List 3 contaminants in a statistically rigorous manner.

10. References

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Appendix A

Statistical Formulas

This appendix contains statistical formulas for the estimation of probabilities of exposure and occurrence, and for means, variances, and confidence intervals for the estimates.

In the following definitions, let h stand for any one of H strata being considered. Typically a stratum will be a combination of system size (Category 1, 2, or 3) and source water type (surface or ground water), so there are H=6 strata. We could also consider just the 3 size strata or 2 source type strata.

We consider a single contaminant of interest where:

M_{hi} = # of people served by the i-th system in h

$\overline{M}_h$ = mean # of people served by each system in h

$$= \frac{1}{N_h}\sum_{i=1}^{N_h} M_{hi}$$

N_h = # of systems in h

n_h = # of systems sampled from h (assume these are system numbers i=1,...,n_h)

y_{hi} = 1 if the contaminant occurs in the i-th system in h; 0 otherwise.

$p_{e,h}$ = probability of exposure for a person served by a system in h

$$= \sum_{i=1}^{N_h} M_{hi} y_{hi} \Big/ \sum_{i=1}^{N_h} M_{hi}$$

p_e = mean probability of exposure for a person of any stratum

$$= \sum_{h=1}^{H} N_h \overline{M}_h p_{e,h} \Big/ \sum_{h=1}^{H} N_h \overline{M}_h$$

$$= \sum_{h=1}^{H} W_{e,h} p_{e,h}$$

$W_{e,h}$ = exposure weight of h

$$= N_h \overline{M}_h \Big/ \sum_{j=1}^{H} N_j \overline{M}_j$$

Now make the simplifying assumption that all systems in a stratum serve the same number of people, that is, $M_{hi} = \overline{M}_h$ for all i. There are three reasons for this assumption. First, it simplifies the estimation and variance formulas below. Second, estimates of the M_{hi} are not readily available, while estimates of the $\overline{M}_h$ are easily obtained from Table 1. Third, the error due to replacing the M_{hi} by $\overline{M}_h$ is likely to be small, since the greatest differences in population per system occur between strata rather than within strata.

Under the above assumption, the expression for $p_{e,h}$ simplifies to:

$$p_{e,h} = \frac{1}{N_h}\sum_{i=1}^{N_h} y_{hi} = \overline{y}_h \qquad \text{(A-1).}$$

Now assuming simple random sampling within each stratum, sample estimates of $p_{e,h}$ and p_e are:

$$\hat{p}_{e,h} = \frac{1}{n_h}\sum_{i=1}^{n_h} y_{hi}$$
$$\hat{p}_e = \sum_{h=1}^{H} W_{e,h}\hat{p}_{e,h} \qquad \text{(A-2).}$$

By Theorem 2.1 of Cochran (1977), $\hat{p}_{e,h}$ is unbiased for $p_{e,h}$, and so $\hat{p}_e$ is unbiased for p_e. By Theorem 2.2 of Cochran (1977):

$$\mathrm{Var}(\hat{p}_{e,h}) = \frac{S_h^2}{n_h}(1 - f_h) \qquad \text{(A-3).}$$

where:

$$f_h = n_h / N_h ,$$
$$S_h^2 = \frac{1}{N_h - 1}\sum_{i=1}^{N_h}(y_{hi} - \bar{y}_h)^2 = \frac{N_h}{N_h - 1}p_{e,h}(1 - p_{e,h}) \qquad \text{(A-4).}$$

and therefore:

$$\mathrm{Var}(\hat{p}_e) = \sum_{h=1}^{H} W_{e,h}^2 \frac{S_h^2}{n_h}(1 - f_h) \qquad \text{(A-5).}$$

A normal-based 100(1-α)% confidence interval for p_e is then $\hat{p}_e \pm z\sqrt{\hat{\mathrm{V}}(\hat{p}_e)}$, where z is the $1-\alpha/2$ quantile of the standard normal distribution, and $\hat{\mathrm{V}}(\hat{p}_e)$ is an estimate of $\mathrm{Var}(\hat{p}_e)$ obtained by substituting $\hat{p}_{e,h}$ for $p_{e,h}$.

The Wilson score interval without continuity correction (Newcombe, 1998; Wilson, 1927) can be adapted to stratified sampling, under the assumption that $p_{e,h} = p_e$ for all h. In this case equations (A-4) and (A-5) give:

$$\mathrm{Var}(\hat{p}_e) = V_e p_e (1 - p_e) \qquad \text{(A-6).}$$

where:

$$V_e = \sum_{h=1}^{H} W_{e,h}^2 \frac{N_h}{n_h(N_h - 1)}(1 - f_h) \qquad \text{(A-7).}$$

Then by repeating the derivation of the Wilson interval, one finds the same limits as in Equation (5), but with n replaced everywhere by V_e^{-1}.

The above equations and derivations for exposure are nearly identical for occurrence. The probability of occurrence, p_o, is defined as the probability that a contaminant occurs within any (randomly selected) system. The probability of occurrence within a given stratum h is:

$$p_{o,h} = \frac{1}{N_h}\sum_{i=1}^{N_h} y_{hi} \qquad \text{(A-8).}$$

(the same as $p_{e,h}$ under the assumption that $M_{hi} = \overline{M}_h$ for all i, above), and:

$$p_o = \sum_{h=1}^{H} W_{o,h} p_{o,h} \qquad \text{(A-9).}$$

where:

$$W_{o,h} = N_h \Big/ \sum_{j=1}^{H} N_j \qquad \text{(A-10).}$$

The remainder of the derivation of means, variances, and confidence intervals is exactly as above, with the subscript e replaced everywhere by o.

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Appendix B

Acronym List

2,4-DNT	- 2,4-dinitrotoluene
2,6-DNT	- 2,6-dinitrotoluene
4,4'-DDE	- 4,4'-dichloro dichlorophenyl ethylene, a degradation product of DDT
Alachlor ESA	- alachlor ethanesulfonic acid, a degradation product of alachlor
AOAC	- Association of Official Analytical Chemists
APHA	- American Public Health Association
ASDWA	- Association of State Drinking Water Administrators
ASTM	- American Society for Testing and Materials
BGM	- Buffalo Green Monkey cells, a specific cell line used to grow viruses
CAS	- Chemical Abstract Service
CASRN	- Chemical Abstract Service Registry Number
CCL	- Contaminant Candidate List
CCR	- Consumer Confidence Reports
CERCLA	- Comprehensive Environmental Response, Compensation & Liability Act
CFR	- Code of Federal Regulations
CFU	- colony forming unit
CFU/mL	- colony forming units per milliliter
CWS	- community water system
DCPA	- dimethyl tetrachloroterephthalate, chemical name of the herbicide dacthal
DCPA mono- and di-acid degradates	- degradation products of DCPA
DDE	- dichloro dichlorophenyl ethylene, a degradation product of DDT
DDT	- dichloro diphenyl trichloroethane, a general insecticide
DNA	- deoxyribonucleic acid
EDL	- estimated detection limit
EPA	- Environmental Protection Agency
EPTC	- s-ethyl-dipropylthiocarbamate, an herbicide
EPTDS	- Entry Point to the Distribution System
ESA	- ethanesulfonic acid, a degradation product of alachlor
FACA	- Federal Advisory Committee Act
FTE	- full-time equivalent
GC	- gas chromatography, a laboratory method
GLI method	- Great Lakes Instruments method
GW	- ground water
GUDI	- ground water under the direct influence (of surface water)
HPLC	- high performance liquid chromatography, a laboratory method

ICR	- Information Collection Request / Rule
IRFA	- initial regulatory flexibility analysis
IMS	- immunomagnetic separation
IRIS	- Integrated Risk Information System
IS	- internal standard
LLE	- liquid/liquid extraction, a laboratory method
MAC	- *Mycobacterium avium* complex
MOA	- Memorandum of Agreement
MCL	- maximum contaminant level
MDL	- method detection limit
MRL	- minimum reporting level
MS	- mass spectrometry, a laboratory method
MS	- sample matrix spike
MSD	- sample matrix spike duplicate
MTBE	- methyl-tertiary-butyl-ether, a gasoline additive
NAWQA	- National Water Quality Assessment Program
NCOD	- National Drinking Water Contaminant Occurrence Database
NDWAC	- National Drinking Water Advisory Council
NERL	- National Environmental Research Laboratory
NPS	- National Pesticide Survey
NTIS	- National Technical Information Service
NTNCWS	- non-transient non-community water system
NTTAA	- National Technology Transfer and Advancement Act
OGWDW	- Office of Ground Water and Drinking Water
OMB	- Office of Management and Budget
PAH	- Poly-aromatic hydrocarbon
PB	- particle beam
PBMS	- Performance-Based Measurement System
pCi/L	- picocuries per liter
PCR	- polymerase chain reaction
^{210}Pb	- Lead-210 (also Pb-210), a lead isotope and radionuclide; part of the uranium decay series
^{210}Po	- Polonium-210 (also Po-210), a polonium isotope and radionuclide; part of the uranium decay series
PWS	- Public Water System
PWSF	- Public Water System Facility
QA	- quality assurance
QC	- quality control
RDX	- royal demolition explosive, hexahydro-1,3,5-trinitro-1,3,5-triazine
RFA	- Regulatory Flexibility Act
RPD	- relative percent difference
RSD	- relative standard deviation

SBREFA	- Small Business Regulatory Enforcement Fairness Act
SD	- standard deviation
SDWA	- Safe Drinking Water Act
SDWIS	- Safe Drinking Water Information System
SDWIS FED	- the Federal Safe Drinking Water Information System
SM	- Standard Methods
SMF	- Standard Compliance Monitoring Framework
SOC	- synthetic organic compound
SPE	- solid phase extraction, a laboratory method
SRF	- State Revolving Fund
STORET	- Storage and Retrieval System
SW	- surface water
TBD	- to be determined
TNCWS	- transient non-community water system
UCMR	- Unregulated Contaminant Monitoring Regulation/Rule
UCM	- Unregulated Contaminant Monitoring
UMRA	- Unfunded Mandates Reform Act of 1995
USEPA	- United States Environmental Protection Agency
UV	- ultraviolet
VOC	- volatile organic compound
µg/L	- micrograms per liter

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Appendix C

Definitions

All monitored systems means all community water systems serving more than 10,000 people, and the national representative sample of community and non-transient non-community water systems serving 10,000 or fewer people that are selected to be part of a State Plan for the UCMR.

Assessment Monitoring means sampling, testing, and reporting of listed contaminants that have available analytical methods and for which preliminary data indicate their possible occurrence in drinking water. All monitored systems must conduct Assessment Monitoring. Assessment Monitoring will be conducted for the UCMR (1999) List 1 contaminants.

Index Systems means a limited number of small CWSs and NTNCWSs, randomly selected from the systems in State Plans, that must monitor for UCMR contaminants and also additionally must report information on system operating conditions (such as water source, pumping rates, and environmental setting). These systems must monitor and report quarterly each year of the 5-year UCMR cycle with EPA paying for all reasonable monitoring costs. This more detailed and regular monitoring of contaminants and operating conditions will provide important information with which EPA can more fully evaluate conditions under which systems operate and will enable comparisons between system operations of similar size and characteristics.

Listed contaminant means a contaminant identified as an analyte in Table 1, 141.40(a)(3) of the Unregulated Contaminant Monitoring Regulation (UCMR). To distinguish the current 1999 UCMR listed contaminants from potential future UCMR listed contaminants, all references to UCMR contaminant lists will identify the appropriate year in parenthesis immediately following the acronym UCMR and before the referenced list. For example, the contaminants included in the UCMR (1999) List include the component lists identified as UCMR (1999) List 1, UCMR (1999) List 2 and UCMR (1999) List 3 contaminants.

Listing cycle means the 5-year period for which each revised UCMR list is effective and during which no more than 30 unregulated contaminants from the list may be required to be monitored. EPA is mandated to develop and promulgate a new UCMR List every 5 years.

Monitoring means (as distinct from Assessment Monitoring), all aspects of determining the quality of drinking water relative to the listed contaminants. These aspects include drinking water sampling and testing, and the reviewing, reporting, and submission to EPA of analytical results.

*Most vulnerable systems (*or *Systems most vulnerable)* means a subset of 5 to not more than 25 systems of all monitored systems in a State that are determined by that State in consultation with the EPA Regional Office to be most likely to have the listed contaminants occur in their drinking waters, considering the characteristics of the listed contaminants, precipitation, system operation, and environmental conditions (soils, geology and land use).

Pre-Screen Testing means sampling, testing, and reporting of the listed contaminants that may have newly emerged as drinking water concerns and, in most cases, for which methods are in an early stage of development. Pre-Screen Testing must be conducted by a limited number of systems (up to 200). The Pre-Screen Testing systems will be selected through the use of a random number generator, and from a list comprised of the States' nominations of up to 25 of the most vulnerable

systems per State. Pre-Screen Testing will be performed to determine whether a listed contaminant occurs in sufficient frequency in the most vulnerable systems or sampling locations to warrant its being included in future Assessment Monitoring or Screening Surveys. Pre-Screen Testing will be conducted for the UCMR (1999) List 3 contaminants.

Random Sampling is a statistical sampling method by which each member of the population has an equal probability (an equal random chance) of being selected as part of a sample (the sample being a small subset of the population which represents the population as a whole).

Representative Sample means a subset of community and non-transient non-community water systems serving 10,000 or fewer people which EPA selects using a random number generator to obtain public water system identification numbers to place them on the first representative sample list. The selection is weighted by population served within a State, water source and then by size categories of 10,000 to 3,301 people, 3,300 to 501 people, and 500 or fewer people; a State may substitute systems from a replacement list of such systems derived through the same method for systems in the first list because a system on the first list is closed, merged or purchases water from another system.

Sampling means the act of collecting water from the appropriate location in a public water system (from the applicable point from an intake or well to the end of a distribution line, or in some limited cases, a residential tap) following proper methods for the particular contaminant or group of contaminants.

Sampling Point means a unique location where UCMR samples are to be collected.

Screening Survey means sampling, testing, and reporting of the listed contaminants for which analytical methods are recently developed and have uncertain potential for occurrence in drinking water by a subset of approximately 300 systems from all monitored systems selected through use of a random number generator for public water system identification numbers. These systems must conduct the Screening Survey for the listed contaminants after public notice and comment to determine whether a listed contaminant occurs at a sufficient frequency and concentration (or density) to warrant being included in future Assessment Monitoring. Two Screening Surveys will be conducted for the UCMR (1999) List 2 contaminants.

State means, for the purposes of this section, each of the fifty States, the District of Columbia, U.S. Territories, and Tribal lands. For the national representative sample, Guam, the Commonwealth of Puerto Rico, the Northern Mariana Islands, the Virgin Islands, American Samoa, and the Trust Territories of the Pacific Islands are treated as a State. Any Indian Tribe which has status as a State under Section 1451 of the Safe Drinking Water Act for this program will be considered as a State.

*State Monitoring Plan (*or *State Plan)* means a State's portion of the national representative sample of CWSs and NTNCWSs serving 10,000 or fewer people which must monitor for unregulated contaminants. A State Plan may be developed by a State's acceptance of EPA's representative sample for that State, or by a State's selection of systems from a replacement list for systems specified in the first list that are closed, merged or purchase water from another system. A State Plan also includes a process by which the State will inform each public water system of its selection for the plan and of its responsibilities to monitor. A State Plan will also include the systems required to conduct Pre-Screen Testing, selected from the State's designation of vulnerable systems.

Stratified Random Sampling is a procedure to draw a random sample from a population that has been divided into subpopulations or strata, with each stratum comprised of a population subset sharing

common characteristics. Random samples are selected from each stratum proportional to that stratum's proportion of the entire population. The aggregate random sample (compiled from all the strata samples) provides a random sample of the entire population that reflects the proportional distribution of characteristics of the population. In the context of the UCMR, the population of public water systems was stratified by size category (based on population served by the water system) and by water source type supplying the water system (ground water or surface water). This stratification was done to ensure that systems randomly selected as nationally representative sample systems would proportionally reflect the actual number of size and water type categories nationally.

Testing means, for the purposes of the UCMR and distinct from *Pre-Screen Testing*, the submission and/or shipment of samples following appropriate preservation practices to protect the integrity of the sample; the chemical, radiological, physical and/or microbiological analysis of samples; and the reporting of the sample's analytical results for evaluation. Testing is a subset of activities defined as *monitoring*.

Unregulated contaminants means chemical, microbiological, radiological and other substances that occur in drinking water or sources of drinking water that are not currently regulated under the federal drinking water program. EPA has not issued standards for these substances in drinking water (i.e., maximum contaminant levels or treatment technology requirements). EPA is required by Congress to establish a program to monitor for selected unregulated contaminants in public water systems to determine whether they should be considered for future regulation to protect public health. The selected contaminants are listed in 141.40(a)(3), Table 1, the UCM List.

Vulnerable time (or *vulnerable period*) means the time (or, in some cases, the 3-month quarter) of the year determined as the most likely to have the listed group of contaminants present at their highest concentrations or densities in drinking water. The vulnerable determination, in the case of the UCMR, is made by the EPA or by the State (under arrangement with the EPA) for a system, subset of systems, or all systems in a State. The vulnerable determination is based on characteristics of the contaminants, precipitation, system operations, and environmental conditions such as soil types, geology, and land use. This determination does not indicate or imply that the listed contaminants will be identified in the drinking water with certainty, but only that sampling conducted during the vulnerable period presumably has the highest likelihood of identifying those contaminants in higher concentrations relative to other sampling times of the year, if and when the contaminants occur.