Parker Environmental Corporation
Creative Solutions for a Complicated Environment

Fill Management Plan
Stafford Street
Parcel ID 35-D1.2-0
Leicester, Massachusetts

March 2022

Lighthouse Environmental Management, LLC

Prepared by:	**Prepared for:**
Parker Environmental Corporation	**Schold Development, Inc.**
97 Walnut Street	**Matt Schold**
Clinton, MA 01510	**77 Chickering Road**
978-273-4263	**Spencer, MA**
sparker@parkerenv.com	

September 2021

Scott Parker, LSP
President

Table of Contents

Attachments

Attachment A – Figures

Figure 1 – Site Locus
Figure 2 – Site Plan
Figure 3 – Grading Plans – Prepared by Tauper Engineering and Survey, Inc.
Figure 4 – MassDEP Receptor Map

Attachment B –

Table 1 - Acceptance Criteria Table
Table 2 – Background Arsenic and Lead Analytical Summary

Attachment C – Laboratory Analytical Reports

Attachment D – Additional Information

- MassDEP Policy WSC#-13-500, “Similar Soils Provision Guidance”
- MassDEP Jar Headspace Screening Procedure (MassDEP Policy #WSC-94-400)
- Lighthouse Profile Form
- USGS Report

1.0 General Background

1.1 Introduction

This Fill Management Plan was prepared by Parker Environmental Corporation on behalf of Lighthouse Environmental Management, LLC (LEM) in support of a Fill Project at the property located on Parcel 35-D 1.2-0 on Stafford Street in Leicester, Massachusetts. The subject plan has been designed to meet the requirements of Leicester's Earth Filling Bylaws and Regulations, and any other applicable Federal or State regulations pertaining to the transport and use of earth for fill. It is my professional opinion that this plan and the proposed regulated activity, once executed and completed, will be substantially protective of human health, public safety, and the environment.

The site locus is shown on **Figure 1** and a Site Plan is included as **Figure 2** in Attachment A. The location and proposed final grading of the proposed fill area is shown on **Figure 3.**

Anticipated sources of fill material include large volumes of excess soil from excavation and construction projects in Massachusetts with elevated levels of naturally occurring arsenic. The intended fill materials include native and reworked sand, gravel, rock and clay with elevated levels of naturally occurring arsenic. It is anticipated that completion of the fill Project will involve importation of approximately 95,000 cubic yards of material, and take approximately 5 years to complete based on available sources of fill materials.

Soil intended for reuse in the filling operation must meet Acceptance Criteria established for this location. Testing of soil prior to acceptance and/or additional documentation of the soil source(s) with background information is required and is described herein.

This plan has been discussed with local and various municipal officials from the Town of Leicester. These discussions provided relevant information regarding the filling operations associated with the Fill Project described within this plan. Therefore, these officials have general awareness of this project and ongoing site activities.

1.2 Parties Involved

Several parties will be involved with the placement of fill material associated with the Stafford St Leicester Fill Project.

1.2.1 Project Location:

Stafford Street
Property ID 35-D1.2-0
Leicester, Massachusetts 01524

1.2.2 Project Proponents

Schold Development
77 Chickering Road
Spencer, MA
508-612-8777 scholddev@gmail.com

1.2.3 Soil Acceptance, Approvals, and Management/Oversight of Filling Operations:

Lighthouse Environmental Management, LLC
184 Stone Street
Clinton, Massachusetts 01510
Phone: 617-699-5245
Kevin Gervais, President
Pradeep Singh, Manager
Email: pradeep@lighthousemgmt.com

1.2.4 Property Owner:

Stafford Street Properties, LLC
83 Keystone Drive
Leominster, MA
508-612-8777 scholddev@gmail.com

1.2.5 Project Daily Filling Operations Manager:

Lighthouse Environmental Management, LLC
184 Stone Street
Clinton, Massachusetts 01510

1.2.6 Independent LSP Review and Approval of Submittal Packages:

Scott Parker, LSP,
Parker Environmental Corporation
97 Walnut Clinton, MA 01510
Phone: 978-273-4263

1.2.7 Emergency Contact:

Lighthouse Environmental Management, LLC
184 Stone Street
Clinton, Massachusetts 01510
Phone: 617-699-5245
Kevin Gervais, President

1.3 Qualifications of Applicant Personnel

Pursuant to the Town of Leicester Zoning By-laws dated June 02, 2020, the qualification of the personnel responsible for adhering to the By-Law and the requirements of the Fill Management Plan are hereby included as follows:

The Operations Manager, Lighthouse Environmental Management, and the Independent LSP, Parker Environmental Corporation are currently operating three locations with a Massachusetts Department of Environmental Protection Administrative Consent Order for Similar Soils filling.

In addition, PEC is retained by the Town of Clinton as an independent reviewer for all soil transported to the Town of Clinton Landfill requiring compliance with MassDEP Corrective Action Design Permit number XX253162.

1.4 Site Security and Site Control

The Site is currently undeveloped. As the development of the property progresses, the property owner, Schold Development and LEM will maintain a system of security cameras at the Site operating 24-hours a day. In addition, natural vegetative barriers are present along the northeast, northwest, southeast, and southwest property lines. At this time, it is anticipated that the northwestern property boundary will be barricaded with fencing as necessary.

1.5 Environmental Monitoring Plan

Fugitive dust will be controlled as described in Section 7.0 of the FMP.

1.6 Site Description

The fill operations associated with the Stafford Street Leicester Fill Project will occur at the property identified as Parcel 35-D1.2-0 and located along Stafford Street in Leicester, Massachusetts. The proposed fill area includes approximately 18 acres of a 37-acre parcel located southeast of Stafford Street along the southwestern portion of the property. The property slopes steeply downward to the south and west from the center of the property toward Stafford Street and Auburn Street and is primarily wooded at this time. The lot is proposed to be cleared and require fill for Site leveling prior to development. See Figures 1, 2 and 3 included in Attachment A.

The property is located in a commercial/residential portion of Leicester with a commercial business located immediately adjacent to the project area to the northwest. To the north are residential properties.

The Stafford Street Leicester Fill Project site is readily accessed from Stafford Street.

The Leicester Assessor’s Office records identify the property as Parcel# 35-D1.2-0. The Assessor’s Office indicates that the parcel is owned by Stafford Street Properties, LLC. The site consists of an irregularshaped parcel of land with a total plan area of approximately 37.22 acres zoned Business Residential-1.

The nearest public water supply consists of a single community public water system comprised of three groundwater wells. Staffordshire Country Estates is the listed community public supply. Wells 2151009-01G, 02G, and 03G are located adjacent to the property. The Zone II Public Water Supply Protection area for two of the wells encompasses portions of the proposed fill area and is shown on **Figure 4 included in Attachment A**. Wetlands have been identified in the southwestern area of the property outside the proposed work.

A review of the Massachusetts Natural Heritage & Endangered Species Program (NHESP) online database was conducted. The proposed fill area is not located within a mapped Priority Habitat for Rare Species or an Estimated Habitat for Rare Species.

2.0 Soil Acceptance Criteria

Soil Acceptance Criteria have been established for various constituents in soil intended for use as fill material at the Stafford Street Leicester Fill Project in compliance with the MassDEP Policy WSC#-13-500, “Similar Soils Provision Guidance”. A copy of this document is included in Attachment D for reference. The Acceptance Criteria were established to be protective of surrounding natural resource areas including nearby community public water supply wells (<500’), nearby wetland areas, construction workers at the site, visitors, and surrounding residents.

2.1 Establishment of Local Background

As documented in the United States Geological Survey (USGS) Scientific Investigations Report 2011-5013, “Arsenic and Uranium in Water from Private Wells Completed in Bedrock of East-Central Massachusetts—Concentrations, Correlations with Bedrock Units, and Estimated Probability Maps”, arsenic is prevalent in groundwater in the Central Massachusetts area, particularly, in Leicester, as seen on Figure 1 of the USGS report, showing documented concentrations of arsenic in public bedrock wells. A copy of the report is included in Attachment D for reference.

In order evaluate local “background” concentrations of arsenic at the Site, Charme Materials collected a series of soil samples from test pits excavated at the Site, in September and November 2021. The locations of the test pits can be found on Figure 2 included in Attachment A. Test pits were excavated to depths of approximately 3 feet below observed grade into material interpreted to be naturally deposited, glacial till. A grab sample was collected from each test pit and submitted to Phoenix Labs for analysis for Total Arsenic and Total Lead. Samples were analyzed for total lead in order to confirm the presence of elevated arsenic was not associated with previous application of lead arsenate pesticides historically used in New England in orchards and leading to increased concentrations of both lead and arsenic in soil.

The results of these analyses are included in Table 2 included in Attachment B. As can be seen from these results, arsenic was reported to be present in the samples at concentrations ranging from 20.2 mg/kg to 59.6 mg/kg. In addition, the samples did not show elevated concentrations of lead correlating to elevated concentrations of arsenic. Based on this evaluation, the maximum background concentration of arsenic has been established at **59** mg/kg. The laboratory reports are included in Attachment D.

The acceptance criteria of less than **59** mg/kg for arsenic is applicable only to soil containing naturally occurring arsenic that meets the notification exemption defined in **310 CMR 40.0317(22),** which applies to arsenic in Boston Blue Clay or arsenic in an area documented by the U.S. Geological Survey or in other scientific literature as an area of elevated arsenic measured in soil or groundwater that (a) is consistently present in the environment at and in the vicinity of the sampling location; (b) is solely attributable to natural geologic or ecologic conditions; and (c) has not been mobilized or transferred to another environmental medium or increased in concentration in an environmental medium as a result of anthropogenic activities.

Ash and/or Solid Waste must only be present in de-minimus quantities not to exceed 5% by volume. Any soil with arsenic detected equal to or greater than 20 mg/kg that does not meet the exemption defined in 310 CMR 40.0317(22) and is subsequently not exempt from reporting to MassDEP, will be treated as “remediation waste” and not accepted at the site. All soil originating from out of state shall have a maximum arsenic concentration less than 20 mg/kg to be considered for acceptance. No exemptions apply for out of state soils.

The proposed Stafford Street Leicester Fill Project is located within 500 feet of residential property and therefore RCS-1 standards apply. Accordingly, in consideration of the Similar Soils Policy, the less than RCS-1 Acceptance Criteria Acceptance Criteria have been established and are presented in “Table 1 – Summary of Soil Acceptance Criteria” included in Attachment B.

3.0 Soil Chemical Testing Requirements

3.1 Required Test Parameters

Test parameters required on soil to be considered for acceptance include:

- Volatile Organic Compounds (EPA 8260) Low-Level
- Semi-volatile Organic Compounds (EPA 8270 full list)
- Metals: MCP 14 metals
- PCBs (<0.1 reporting limit)
- Total Petroleum Hydrocarbons (summation of EPH Fractions may be substituted)
- Hexavalent Chromium if Total Chromium > 100 mg/kg
- pH/Corrosivity
- Specific Conductance (conductivity) (may be excluded or limited based on site history)
- Field Screening for Total Organic Vapors (PID following MassDEP Jar Headspace Screening Procedure based upon an isobutylene response factor, and the frequency may be limited based on site history and LSP Opinion relative unimpacted naturally deposited soil)
- Herbicides (may be excluded or limited based on site history)
- Pesticides (may be excluded or limited based on site history)
- Ignitibility/Flash point (may be excluded or limited based on site history)
- Reactive Cyanide (may be excluded or limited based on site history)
- Reactive Sulfide (may be excluded or limited based on site history)
- TCLP for any analyte exceeding EPA TCLP Trigger Values (20 times rule)
- Others as deemed prudent based on soil source site history

Current and appropriate versions of applicable methods are to be used in accordance with MassDEP Compendium of Analytical Methods. Detection limits for analyses must be appropriate for comparison to Acceptance Criteria. Generator and Qualified Environmental Professional/LSP must ascertain data is appropriate for use as intended.

Required Chemical Testing and Frequency

Testing is required at the minimum frequencies below for reuse at the Fish Road Reclamation Project site:

	General Source/Origin Description	Minimum Test Profile Frequency
1	Naturally Deposited Soil containing no fill materials. Excludes soil from sources meeting Categories 2, 3, 4, 5 or 6 criteria below.	1 test profile per 1,000 cubic yards (1,500-1,700 tons) for initial review.
2	Naturally Deposited Soil from areas of known or suspected naturally occurring high background levels of constituents and containing no fill materials. Excludes soil from sources meeting Categories 3, 4, 5 or 6 criteria below.	1 test profile per 1,000 cubic yards (1,500-1,700 tons) for initial review.
3	Naturally Deposited Marine Soils and Boston Blue Clay containing no fill materials. Excludes soil from sources meeting Categories 5 or 6 criteria below.	1 test profile per 1,000 cubic yards (1,500-1,700 tons) for initial review.
4	Fill Materials: Soil, sediments, rock and/or stone obtained off site that was used to fill holes or depressions, create mounds, or otherwise artificially change the grade or elevation of real property. This category includes, but is not limited to urban and non-urban fill, and any natural soil/fill mixture.	1 test profile per 500 cubic yards (750- 850 tons) for initial review. Additional test parameters such as cyanide and asbestos may be required.
5	Soil from Industrial, Commercial or Manufacturing site with history of any of the following: tannery, textiles, chemical/ paint production, circuit board manufacturing, plating/metal finishing, foundry operations, coal gasification, dry cleaning, salvage yards, pesticide/ herbicide use, storage or distribution. An LSP, LSRP or LEP must provide a report detailing why such soils conform to the Fish Road Reclamation Project.	1 test profile per 500 cubic yards (750- 850 tons) for initial review. Additional test parameters based on site history may be required.
6	Soil from sources not otherwise described above where historic test data indicate potential exceedance of any SSAC or where past use or storage of OHM at more than household quantities.	1 test profile per 500 cubic yards (750- 850 tons) for initial review. Additional test parameters based on historic test data may be required.
7	Rock: Blasted or excavated ledge or bedrock.	One test for perchlorate per 500 cy, unless Generator demonstrates that no perchlorate blasting agents were used. One geochemical characterization profile per 500 cy including Acid Base Accounting and Net Acid Generation Potential unless Generator demonstrates that the rock is not known or suspected to contain sulfide minerals.

For acceptance purposes, soil density will be considered 1.5 tons per cubic yard for soil sampled from a stockpile, and no greater than 1.7 ton per cubic yard for soil sampled in-situ via borings or test pits. Further technical justification will be required for acceptance of soil with assumed density greater than 1.7 ton per cubic yard.

3.2 Test Data Quality and Usability

Test data provided for review and acceptance must be considered current. If aged data (greater than 1 year old) is to be utilized for acceptance, a statement from the qualified environmental professional making the submittal must be provided indicating site conditions have not changed since collection of data and that no documented releases that may impact site conditions have occurred since data was collected.

All analytical testing must report a laboratory detection limit that is less than applicable Acceptance Criteria for a given constituent. Consistent with the Compendium of Analytical Methods and 310 CMR 40.000, the use of routine volatile organic compound test methods with typical reporting limits is sufficient as long as technical justification is provided by the LSP-of-Record that the soil being tested is unlikely to contain the less common compounds such as 1,4 dioxane based on Site history and other relevant site-specific information. Prior to submittal, the environmental professional making the submittal must perform a QA/QC evaluation of the data to document that data is representative and usable for its intended purpose.

3.3 Field Screening Requirement

Soil must be field screened for Total Organic Vapors following the MassDEP Jar Headspace Screening Procedure (MADEP Policy #WSC-94-400 included Attachment D, modified to be based upon an isobutylene response factor rather a Benzene standard). Soil must be field screened at the time of excavation, stockpiling or load out to the Stafford Street Leicester Fill Project at a frequency of 1 field screening test per approximately 50 cubic yards of soil. Soil must contain less than 5 parts per million volume (ppmv) total organic vapors (TOV) above ambient background by the jar headspace screening procedure to meet Acceptance Criteria. Natural organic soils which exhibit TOV screening levels above 5 ppmv may be considered for acceptance on a case-by-case basis provided the following: results of analytical testing, particularly VOC analysis, identifies no exceedances of acceptance criteria; source of elevated TOV screening levels can be attributed to a source other than oil or hazardous material (such as hydrogen sulfide interference on PID). All soil proposed for reuse shall not have an unpleasant odor. Frequency of screening may be modified pending an LSP Opinion indicating the material is naturally deposited and unimpacted.

3.4 Visual Requirement

Soil will exhibit no indication of staining or other discoloration indicative of a release or impact of oil or hazardous material or other nuisance conditions. Soil and fill materials approved for use at the property shall contain no more than 5% Asphalt, Brick and Concrete (“ABC”) material. Any such ABC material must measure less than 6 inches in any dimension and acceptance of such soil will be considered on a case-by-case basis. Soil and fill materials approved for use at the property may contain de-minimus quantities, not to exceed 5%, of ash and/or Solid Waste (e.g. Municipal Solid Waste and/or Construction and Demolition Waste) as defined in 310 CMR 16.00 and 310 CMR 19.000. The acceptance of Remediation Waste, as defined at 310 CMR 40.0006, is prohibited.

3.5 QA/QC Requirement

Lighthouse Environmental Management, may on a random basis select a load arriving to the Stafford Street Leicester Fill Project for a QAQC Inspection and instruct the driver to dump in the designated QAQC, quarantine area. LEM will inspect the load visually, screen the soil with a PID and collect a soil sample for laboratory analysis. Loads arriving with material not meeting acceptance criteria or determined to contain contaminants at levels at or exceeding acceptance criteria based on QAQC sampling will be rejected and removed from the site **at the expense of the Generator** of that material. Loads not meeting acceptance criteria at the time of delivery to the project site due to debris, odors, or other nonconformance with Acceptance Criteria will be rejected prior to off-loading or reloaded immediately by LEM. Such loads will be removed from the project site immediately in the truck they were delivered in. Should QA/QC testing indicate soil as delivered is not below Acceptance Criteria, then the Generator of that soil and the party contracting with LEM for placement of soil at the site will promptly remove such soil from the project site. Should the Generator and/or contracting party not promptly remove unacceptable soil, LEM will promptly act to remove that soil from the project site. LEM will pursue cost recovery from the Generator and/or the contracting party for all costs associated with removal from the site if soil is not below all Acceptance Criteria. Additional soil will not be accepted from a source where soil failed a random QA/QC test or soil was rejected from the site upon arrival until an appropriate resolution is reached.

4.0 Soil Submittal and Approval Process

A Soil Submittal Package must be provided by representatives of each soil source/origin for review and approval by representatives of the Stafford Street Leicester Fill Project.

A complete package is to be provided to:
Lighthouse Environmental Management, LLC
184 Stone Street
Clinton, Massachusetts 01510
Pradeep Singh, Manager
Email: pradeep@lighthousemgmt.com

A complete LSP/QEP Opinion package should include the following information:

- Description of generating Site including:
    - Address;
    - current use of the property;
    - history of known uses of the property;
    - description of surrounding area;
- Site Plan showing location(s) of excavation(s) and sample locations;
- Description of material proposed to be shipped including observations of soil quality and type, boring or well logs or test pit logs if appropriate;
- Description of representative sampling process including:
    - Number and location of composite sample subsample locations; for stockpile sampling, a 5-8 subset sample composite is recommended;
    - field PID screening results;
    - method of selection of VOC sample for laboratory analysis;
- Tabulated analytical results with comparison to Stafford Street Leicester Fill Project SAC;
- Laboratory analytical results;
- Completed and signed Material Shipping Record;
- Completed and signed Lighthouse Profile form – included in Attachment D;
- A specific declaration/Opinion that the material proposed to be sent to the Stafford Street Leicester Fill Project meets the requirements described herein;
- Other considerations:

- Based on Generator/LSP/QEP knowledge, any other testing or considerations that are appropriate to characterize the material such as dioxins, asbestos, herbicides and pesticides, (if herbicides and pesticides are not deemed necessary, the text of the opinion should state this and why)

After initial approval is gained, the package will be sent to the Site LSP for review. Characterization results from each candidate property will be reviewed to confirm that the soil meets the requirements set forth in this plan.

The Site LSP will then prepare an acknowledgement and approval letter to the owner and Lighthouse confirming the acceptance of the soil for confirmatory signature by Lighthouse. The letter will specify the approved quantity, the quantity to be shipped, dates, restrictions (if any), and other pertinent items. The letter will be forwarded by Lighthouse to the generator. LEM will perform a preliminary review to establish whether the submittal is complete and soil is appropriate for reuse as fill material at the Stafford Street Fill Project site. The submittal will then be forwarded to the independent Licensed Site Professional contracted by LEM to perform the final review and approval.

Upon completion of the initial review, supplemental information, clarification, or additional delineation/frequency testing can be requested prior to acceptance. The source making the submittal must provide the information, clarification, or additional test data as requested for the approval process to proceed.

The review process will typically take from 2 to 4 business days depending on the number of submittals in the queue for review, the amount of soil requested for approval, and available capacity.

5.0 Site Access

The Stafford Street Project site is readily accessed from Stafford Street. Rt 9 in Worcester is located approximately 2 miles to the northeast of the project site via Stafford Street.

Normal operating hours are approximately 7:00 AM to 4:00 PM Monday through Friday. Some allowance can be made until 5 pm for late loads with advanced notice. Saturdays are available for an additional fee with advanced notice.

6.0 Overweight Truck Policy

Any truck entering the Stafford Street Leicester Fill Project exceeding 10% of the maximum allowable MassDOT gross vehicle weight will be subject to the following penalties:

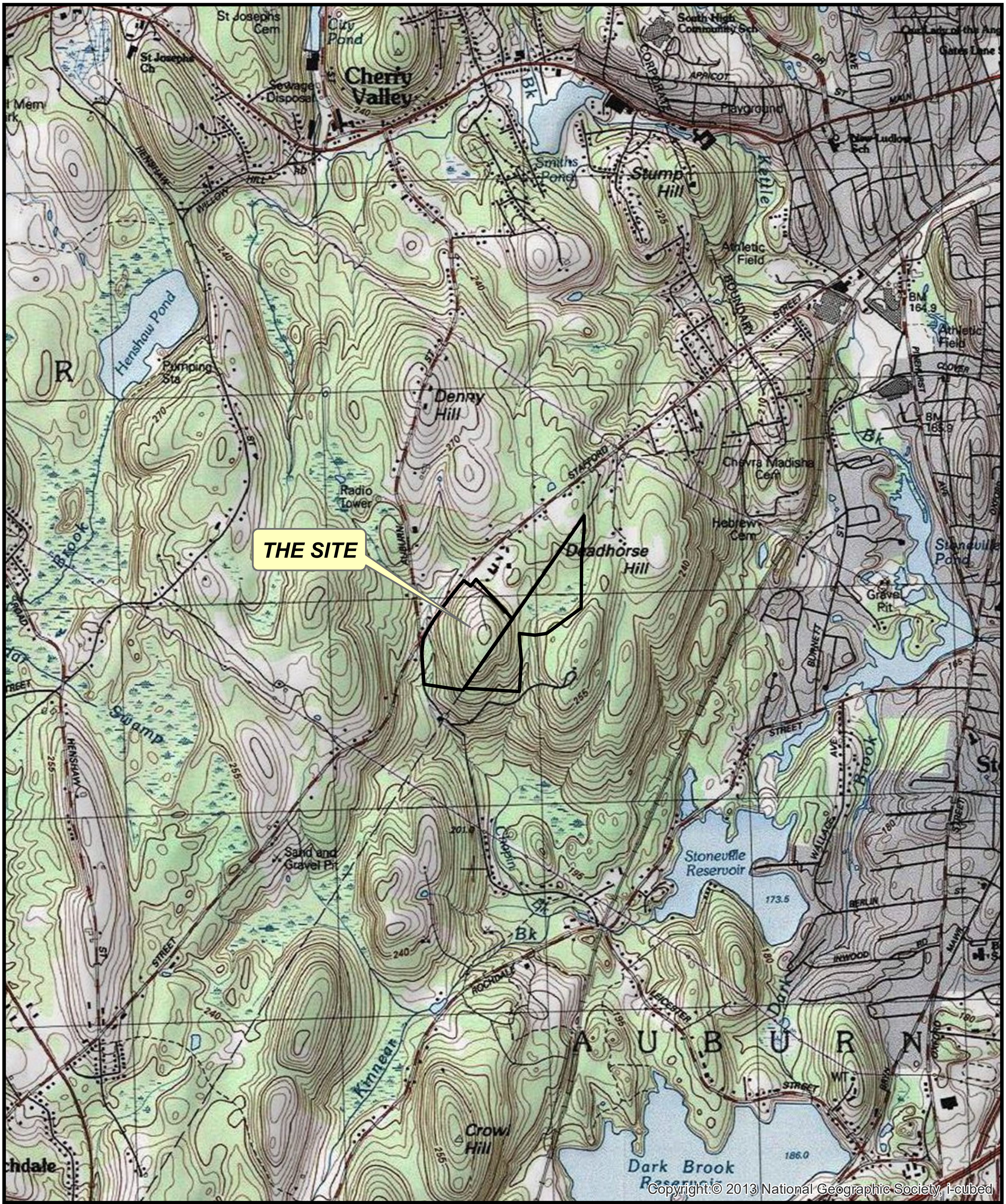
- 1st offense – verbal warning
- 2nd offense – 1 hour penalty timeout
- 3rd offense – 2 hour penalty timeout
- 4th offense – In person meeting with Project Proponents and truck owners/operators to review the facility truck policy and expectations with the potential of being banned from future deliveries to this site.

7.0 Dust and Sediment Control Plan

The Stafford Street Leicester Fill Project will use the following measures to mitigate dust and sediment at the project site:

- A water truck will be utilized as needed to control dust;
- Gravel tracking pad has been installed at the entrance to the site and will be replaced as needed to control sediment tracking on town roadways;
- Roads will be swept as needed to control dust and soil from tracking on to pubic roadways;
- Filling operations will be suspended when winds exceed 40 miles per hour.

ATTACHMENT A
FIGURES



N
W E
S

0 500 1,000 2,000

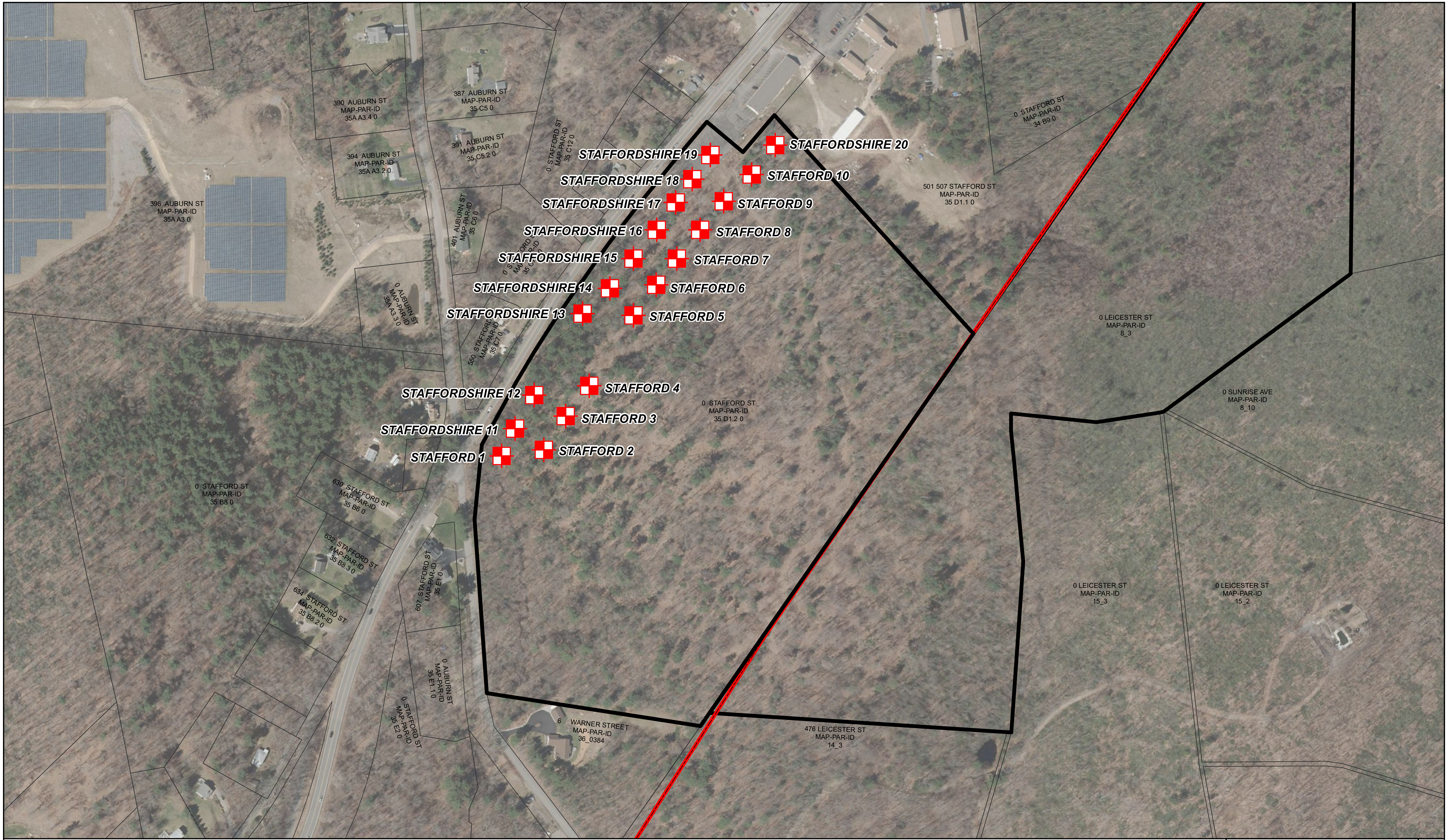
Feet

LOCUS MAP
STAFFORD STREET
LEICESTER, MASSACHUSETTS

FIGURE 1

Ref: LocusMap.mxd
Drafted By: JAF
Date: 12/01/21
Source: MassGIS

Parker Environmental
Creative Solutions for a Complicated Environment



ASSESSORS PARCEL OF INTEREST

OTHERS ASSESSORS PARCELS

TEST PIT

Parker Environmental
Creative Solutions for a Complicated Environment

SITE MAP
STAFFORD STREET
LEICESTER, MASSACHUSETTS

REF:

Drafted By: JAF
Date: 12/02/21
Source: MassGIS, ArcGIS, USGS

FIGURE 2

SPECIAL PERMIT/SITE PLAN
at
STAFFORD STREET
MAP 5, LOT D1.2
LEICESTER, MA

NOTE:

1.) PROPERTY LINES/SITE FEATURES ARE TAKEN FROM PLAN PREPARED BY J.R. RUSSO & ASSOCAITES ENTITLED AS-BUILT PLAN FOR 1439 MAIN STREET LEICESTER MA DATED 9-23-10.

2.) THE PURPOSE OF THIS PLAN IS FOR THE PREPORATION OF THE EXISTING PARCEL LOCATED AT 1439 MAIN STREET FOR FUTURE A DEVELOPMENTAL.

3.) MATERIALS AND CONSTRUCTION PRACTICES SHALL BE IN CONFORMANCE WITH THE LATEST EDITION OF THE TOWN OF LEICESTER'S DEPARTMENT OF PUBLIC WORKS & PARKS STANDARD SPECIFICATIONS & DETAILS, UNLESS OTHERWISE SPECIFIED BY LOCAL AUTHORITY OR THE ENGINEER.

4.) THE CONTRACTOR SHALL UTILIZE ALL MEASURES AND MATERIALS NECESSARY TO ENSURE THE SAFETY OF ALL PERSONS AND PROPERTIES AT THE SITE DURING CONSTRUCTION. ALL EXCAVATIONS SHALL CONFORM TO CURRENT OSHA STANDARDS.

5.) UNLESS OTHERWISE NOTED, ALL DISTURBED AREAS SHALL BE DRESSED WITH A MINIMUM OF FOUR INCHES (4") OF LOAM AND SHALL BE SEEDED WITH AN APPROVED GRASS MIX.

6.) THE CONTRACTOR SHALL PROVIDE APPROPRIATE EROSION AND SEDIMENTATION CONTROL MEASURES AT ALL TIMES. DEWATERING OPERATIONS SHALL BE PROVIDED, IF REQUIRED; ALL DISCHARGE SHALL PASS THROUGH SEDIMENTATION CONTROL DEVICES TO PREVENT IMPACTS UPON WATER BODIES, BORDERING VEGETATED WETLANDS, DRAINAGE SYSTEMS AND ABUTTING PROPERTIES.

7.) DISTURBED AREAS SHALL BE STABILIZED BY LOAMING AND SEEDING SOON AFTER THE FINISHED GRADE HAS BEEN MET. IF FINAL GRADING DOES NOT OCCUR DURING THE GROWING SEASON, THESE AREAS SHALL BE MULCHED WITH HAY SECURED BY WEIGHTED SNOW FENCE, CHICKEN WIRE MESH OR JUTE NETTING WITH STAPLES. SEED FOR PERMANENT GRASS COVER SHOULD BE ACCORDING TO SOIL CONSERVATION SERVICE GUIDELINES FOR SOIL AND MOISTURE CONDITIONS FOUND ON THE SITE.

8.) SEDIMENTATION CONTROL FENCE AND/OR HAY BALES SHALL BE MAINTAINED UNTIL ALL SLOPES HAVE BEEN STABILIZED AND THERE IS NO DANGER OF EROSION DIRECTLY ONTO ABUTTING PROPERTIES.

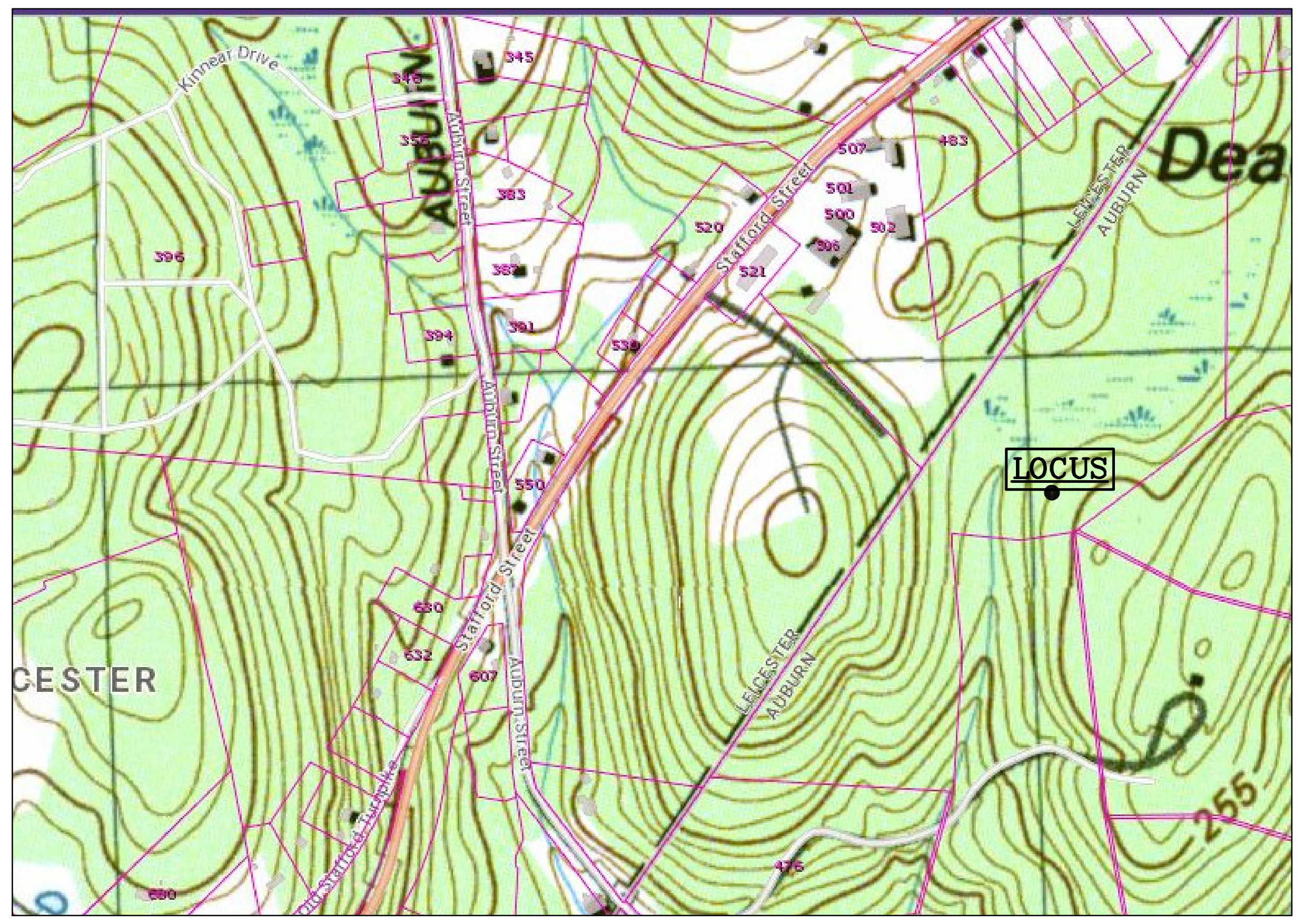
9.) PRIOR TO INITIATING CONSTRUCTION, SEDIMENTATION CONTROL DEVICES SHALL BE INSTALLED . THE CONTRACTOR SHALL MAINTAIN THE DEVICES UNTIL ALL WORK IS COMPLETE AND ALL AREAS HAVE BEEN STABILIZED.

10.) IF THE PROPOSED ROADWAY AREAS ARE NOT PAVED IMMEDIATELY AFTER THE INSTALLATION OF THE DRAINAGE STRUCTURES, HAY BALES SHALL BE PLACED TO PROTECT THE INTEGRITY OF THE STRUCTURES.

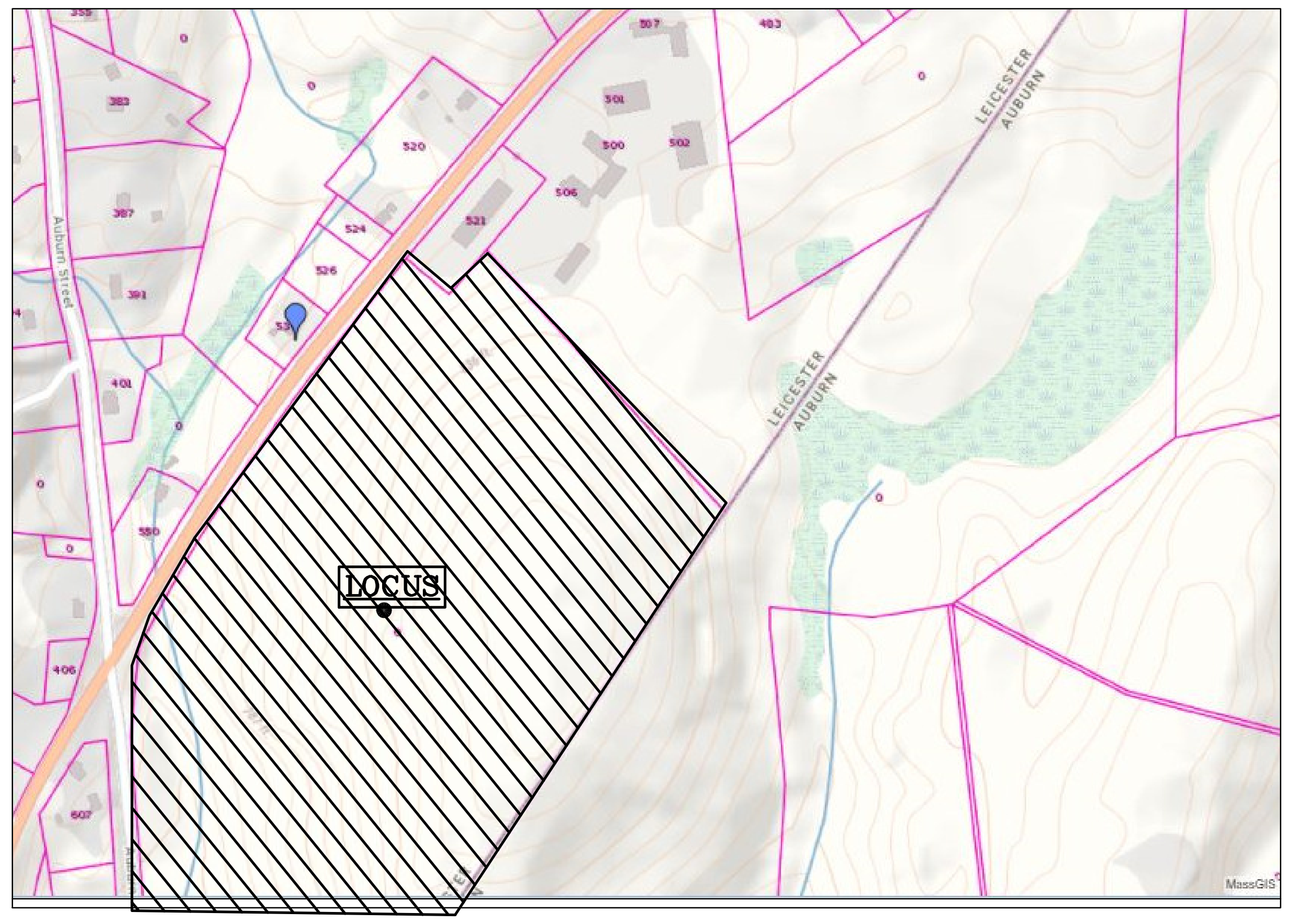
11.) THE LOCATION OF UNDERGROUND UTILITIES AND STRUCTURES ARE BASED ON FIELD AND RECORD INFORMATION. THE ENGINEER DOES NOT GUARANTEE THEIR ACCURACY OR THAT ALL UTILITIES AND SUBSURFACE STRUCTURES ARE SHOWN. THE CONTRACTOR SHALL VERIFY SIZE, LOCATION AND INVERT ELEVATIONS OF STRUCTURES AND UTILITIES, AS REQUIRED PRIOR TO THE START OF CONSTRUCTION. ANY DISCREPANCIES WITH RECORD DATA SHALL BE REPORTED TO THE ENGINEER IMMEDIATELY. PRIOR TO, AND DURING CONSTRUCTION, THE CONTRACTOR SHALL NOTIFY AND COORDINATE WITH THE LOCAL UTILITY COMPANIES, WITH THE TOWN OF STURBRIDGE'S HIGHWAY DEPARTMENT, OTHER TOWN UTILITY DEPARTMENTS, APPLICABLE PRIVATELY OWNED UTILITY COMPANIES AND DIG-SAFE (1-888-344-7233) TO VERIFY UTILITY LOCATION AND TO PROTECT UTILITIES DURING AND AFTER CONSTRUCTION.

12.) THE CONTRACTOR SHALL PROVIDE FOR ALL TRAFFIC CONTROL IN ACCORDANCE WITH THE TOWN OF LEICESTER REQUIREMENTS.

13.) NO TRENCHES SHALL BE ALLOWED TO REMAIN OPEN OVERNIGHT.



LOCUS "USGS" MAP



LOCUS "ASSESSORS" MAP

LIST OF DRAWINGS:

SHEET - 1	COVER SHEET
SHEET - 2	EXISTING CONDITIONS
SHEET - 3	GRADING PLAN
SHEET - 4	DETAILSHEET

Y:\Land Projects\Land Projects 2021\StaffordShire\21-301 SPEICAL PERMIT-SITE PLAN STAFFORD ST LEICESTER.dwg

P.E.	P.L.S.

APPROVAL UNDER SITE PLAN REVIEW.
LEICESTER PLANNING BOARD

BEING A MAJORITY

____
____
____
____
____

APPROVAL DATE:______________

ENDORSEMENT DATE:______________

REVISIONS

REV.	DATE	DESCRIPTION

PROJECT NO.	21-301
DESIGNED BY	PML
CHECKED BY	AB
DATE	10/5/21
CAD FILE	21-301 SPECIAL PERMIT

PREPARED BY:
TAUPER
Engineering & Survey, Inc.
710 MAIN STREET
OXFORD, MA 01537
P:(508) 987-8713 F:(508) 987-8714

SHEET TITLE

COVER SHEET

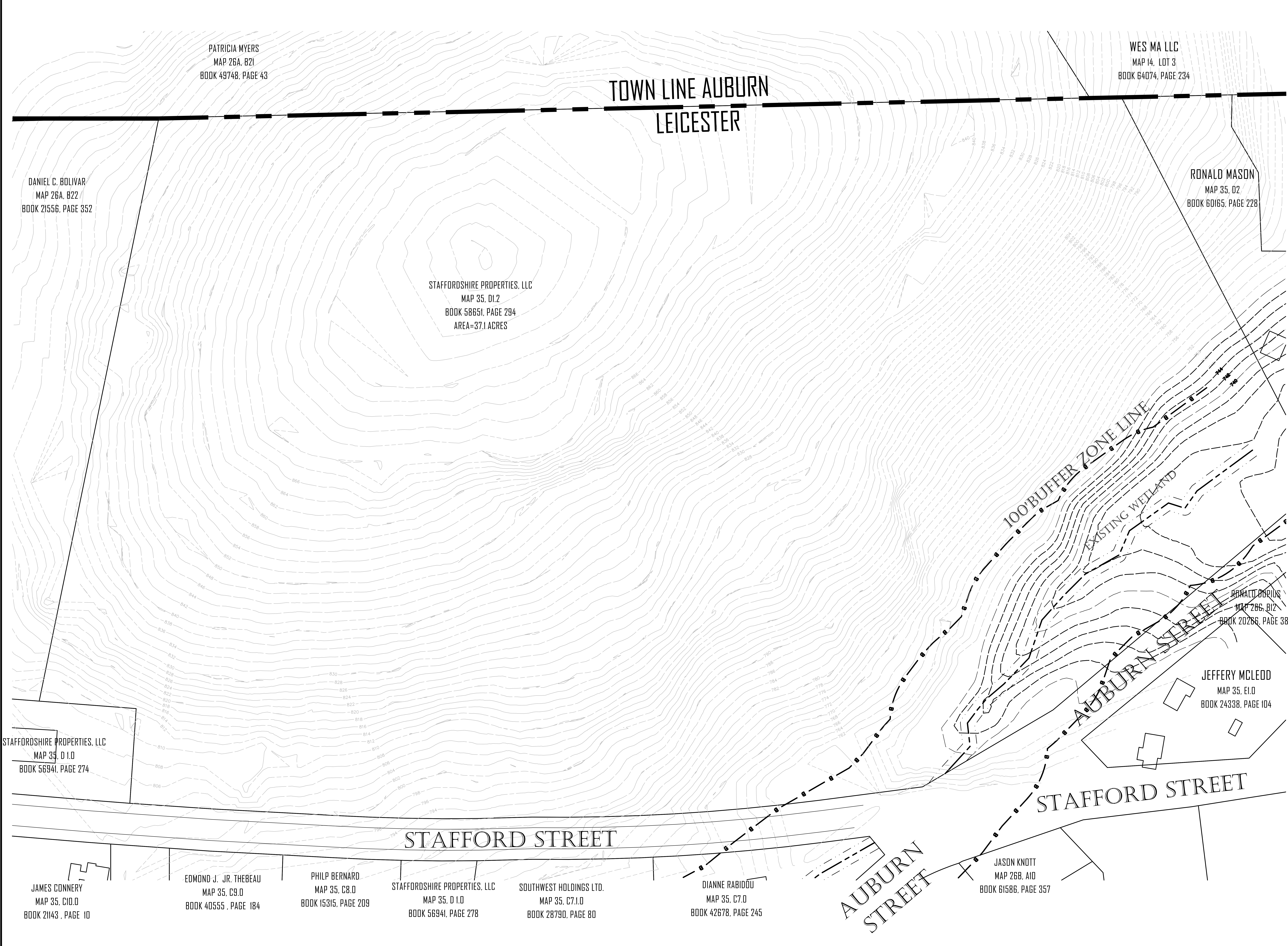
SPECIAL PERMIT PLAN
at
STAFFORD STREET

LEICESTER, MA
PREPARED FOR
STAFFORDSHIRE

SHEET NO.

C-1.0

Y:\Land Projects\Land Projects 2021\StaffordShire\21-301 SPEICAL PERMIT-SITE PLAN STAFFORD ST LEICESTER.dwg



P.E.	P.L.S.

APPROVAL UNDER SITE PLAN REVIEW,
LEICESTER PLANNING BOARD

BEING A MAJORITY

APPROVAL DATE:________________

ENDORSEMENT DATE:________________

REVISIONS

REV.	DATE	DESCRIPTION

PROJECT NO.	21-301
DESIGNED BY	PML
CHECKED BY	SB
DATE	3/3/22
CAD FILE	21-301 SPECIAL PERMIT

GRAPHIC SCALE

60 0 30 60 120

(IN FEET)
1 inch = 60 feet

PREPARED BY:

TAUPER
Engineering & Survey, Inc.
710 MAIN STREET
OXFORD, MA 01537
P:(508) 987-8713 F:(508) 987-8714

SHEET TITLE

EXISTING CONDITIONS

SPECIAL PERMIT PLAN
at
STAFFORD STREET

LEICESTER, MA
PREPARED FOR
STAFFORDSHIRE

SHEET NO.

C-2.0

NOTES:
[1] SLOPE SURFACE SHALL BE FREE OF ROCK, CLODS, STICKS AND GRASS, MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT
[2] APPLY PERMANENT SEEDING BEFORE PLACING BLANKETS
[3] LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL. DO NOT STRETCH
[4] MATS/BLANKETS SHOULD BE INSTALLED VERTICALLY DOWNSLOPE
[5] TAMP SOIL OVER MAT/BLANKET

PART 3 – EXECUTION

3.01 THROUGHOUT CONSTRUCTION

A. DEVISE WORK SEQUENCE SO AS TO LIMIT DRAINAGE AREA THAT IS TRIBUTARY TO DISTURBED AREAS. DEVISE, EMPLOY, AND MAINTAIN CONTROL MEASURES SUCH AS DIVERSION CHANNELS AND BERMS, STRATEGICALLY LOCATED STOCKPILES, AND SEDIMENT BASINS TO SUBDIVIDE DRAINAGE AREAS INTO SMALL, MANAGEABLE SUBAREAS, THEREBY MINIMIZING RUNOFF AND THE POTENTIAL FOR EROSION.

B. MAINTAIN BARRIER AT LIMIT OF WORK AND PROTECT EXISTING VEGETATION / FACILITIES OUTSIDE OF LIMIT OF WORK.

C. MAINTAIN SPARE MATERIAL STOCKPILES FOR IMMEDIATE EMPLOYMENT / REPAIR / EXPANSION OF CONTROL MEASURES. AT A MINIMUM, SUCH MATERIALS SHALL INCLUDE HAY BALES, SILT FENCE AND STAKES, AND CRUSHED STONE.

D. INSPECT AND MAINTAIN EFFECTIVENESS OF CONTROL MEASURES BY REPAIRING AS NECESSARY TO ENSURE INTENDED FUNCTION; BY SUPPLEMENTING AS NECESSARY FOR ADEQUATE EXTENT; BY REMOVING TRAPPED PRODUCTS OF EROSION AS NECESSARY TO MAINTAIN EFFECTIVE TRAP VOLUME.

E. LIMIT EXTENT OF WORK AREA SO THAT ALL DISTURBED AREAS CAN BE STABILIZED WITH CONTROL MEASURES WITHIN A 24–HOUR PERIOD.

F. INSTALL CONTROL MEASURES AS SOON AS PRACTICABLE AFTER EACH MANAGEABLE PORTION OF EARTHWORK IS COMPLETE. EMPLOY TEMPORARY MEASURES AS NECESSARY TO STABILIZE DISTURBED AREAS, EVEN WHERE SUBSEQUENT CONSTRUCTION OPERATIONS MAY REQUIRE RE–DISTURBANCE.

G. WHEN INTENSE RAINFALL IS EXPECTED, CONSIDER, DEVISE, AND EMPLOY REINFORCING CONTROL MEASURES PRIOR TO THE RAINFALL EVENT TO MEET THE REQUIREMENTS DESCRIBED IN 1.01.A. IF NECESSARY, EMPLOY TEMPORARY CONTROL MEASURES ON MATERIAL STOCKPILES TO COUNTERACT POTENTIAL SEDIMENT TRANSPORT DURING INTENSE RAINFALL.

H. WHEN VEHICLE REFUELING IS REQUIRED ON SITE, CONDUCT REFUELING OPERATIONS OUTSIDE OF ENVIRONMENTALLY SENSITIVE AREAS.

I. PROPERLY DISPOSE OF DEBRIS, SOLID WASTE, TRASH, AND CONSTRUCTION WASTE / BYPRODUCTS OFF SITE.

J. SWEEP ON–SITE PAVED AREAS AND OFF–SITE STREETS AS NECESSARY TO PREVENT SILT AND DEBRIS ORIGINATING ON SITE FROM ENTERING CLOSED DRAINAGE SYSTEMS AND / OR ENVIRONMENTALLY SENSITIVE AREAS. WHEN NECESSARY UTILIZE WATER SPRAYING, SURFACE ROUGHENING AND/OR APPLY POLYMERS, SPRAY–ON TACKIFIERS, CHLORIDES AND BARRIERS FOR DUST CONTROL.

K. INSPECT EROSION CONTROLS DAILY THROUGHOUT CONSTRUCTION REPAIR DAMAGED CONTROLS IMMEDIATELY.

3.02 SITE PREPARATION AND ACCESS

A. WALK SITE AND IDENTIFY LOCATIONS OF LIMIT OF WORK AND ENVIRONMENTALLY SENSITIVE AREAS. ESTABLISH CONSTRUCTION STAGING AREA, LOCATED BEYOND ENVIRONMENTALLY SENSITIVE AREAS.

B. INSTALL CONTROL MEASURES AS SHOWN ON THE DRAWINGS, INCLUDING THOSE DEFINING THE LIMIT OF WORK.

C. LIMIT VEHICULAR TRAFFIC TO AND FROM SITE TO MINIMIZE TRANSPORT OF SEDIMENT.

3.03 CLEARING, GRUBBING, AND STRIPPING

A. SCHEDULE GRUBBING AND STRIPPING TO OCCUR IMMEDIATELY PRIOR TO EARTH DISTURBANCE. DEPENDING ON SITE AREA, CONSIDER MULTIPLE GRUBBING PHASES, SEQUENCED TO TAKE ADVANTAGE OF THE EROSION PREVENTION POTENTIAL OF EXISTING VEGETATIVE COVER.

B. MINIMIZE THE AREA OF EXISTING VEGETATION REMOVED WHEREVER POSSIBLE. NO GREATER THAN FIVE (5) ACRES SHALL BE UNSTABLE AT ANY TIME.

C. LOCATE AND SIZE STOCKPILES TO MINIMIZE EROSION POTENTIAL, TAKING ADVANTAGE OF TERRAIN SLOPE AND ASPECT, WHERE APPROPRIATE.

D. PROTECT VEGETATION, INCLUDING ROOT SYSTEMS, BEYOND LIMIT OF CLEARING.

E. PROCESS TIMBER, STUMPS, SLASH, AND BRUSH SO AS TO PROTECT ENVIRONMENTALLY SENSITIVE AREAS AND INSTALLED CONTROL MEASURES. PROPERLY DISPOSE OF EXCESS OFF SITE. BURIAL OF STUMPS ON SITE IS PROHIBITED.

3.04 EXCAVATION FOR BUILDING FOUNDATIONS AND UTILITIES

A. DEVISE AND INSTALL CONTROL MEASURES ADEQUATE TO HANDLE DISCHARGES AND TRAP SEDIMENT FROM FOOTING SUMP AND WELL POINT PUMPS PRIOR TO EXCAVATION.

B. ARMOR SUMP PUMP DISCHARGE LOCATIONS TO PREVENT EROSION AT POINT OF DISCHARGE AND AREAS DOWNSTREAM.

C. IF FOUNDATION EXCAVATIONS GRADE TO DAYLIGHT ON THE LOW SIDE, DEVISE AND INSTALL CONTROL MEASURES TO HANDLE SURFACE AND GROUNDWATER FLOW FROM EXCAVATION LOW POINT.

D. STOCKPILE EXCAVATED MATERIALS TO BAFFLE OVERLAND RUNOFF, AVOIDING THE CREATION OF LENGTHY PATHS OF CONCENTRATED RUNOFF. STOCKPILE SLOPES SHALL NOT EXCEED 2:1.

E. BACKFILL UTILITY TRENCHES AS SOON AS PRACTICABLE TO PREVENT FLOODING, SLOUGHING, POTENTIAL OVERFLOW, AND REPETITIVE EARTH DISTURBANCE.

3.05 SITE GRADING

A. WHERE APPLICABLE, FOLLOW EXCAVATION AND FILL PRACTICES SHOWN ON DRAWINGS TO LOCALIZE AND MINIMIZE EROSION.

B. MONITOR SEDIMENT VOLUME IN TEMPORARY SEDIMENT BASINS AND AT DIVERSION BERMS AND CHECK DAMS. IN ALL AREAS EXCEPT THOSE THAT DO NOT PRESENT POTENTIAL PROBLEMS WITH REGARD TO FUTURE SOIL STABILITY, DRAINAGE, OR BEARING CAPACITY, REMOVE AND PROPERLY DISPOSE OF TRAPPED SEDIMENT BEFORE BRINGING SITE TO FINAL SUBGRADE.

C. EXPOSED SOILS SHALL BE PERMANENTLY STABILIZED WITHIN FIVE (5) BUSINESS DAYS OF COMPLETION OF CONSTRUCTION OF A GIVEN AREA. EXPOSED AREAS WHERE NO WORK HAS OCCURRED FOR FOURTEEN (14) DAYS SHALL BE TEMPORARILY STABILIZED WITH HYDROSEED OR OTHER APPROVED METHOD.

D. SLOPES STEEPER THAN 3:1 SHALL BE STABILIZED IMMEDIATELY AFTER COMPLETION.

E. SLOPES STEEPER THAN 3:1 SHALL BE TEMPORARY STABILZIED WITH STUMP GRINDING FOR NO MORE THAN 2 YEARS OR UNTIL THE PAD SITE HAS BEEN FINAL GRADED FOR PROPOSED DEVELOPMENT.

3.06 LANDSCAPING

A. COMPLETE LANDSCAPING AS SOON AS POSSIBLE AFTER COMPLETION OF FINAL SUBGRADE.

B. IMMEDIATELY AFTER PLACEMENT OF TOPSOIL, STABILIZE WITH CONTROL MEASURES INCLUDING, BUT NOT NECESSARILY LIMITED TO, SEED MIX, MULCH, AND / OR BLANKET.

C. PERMANENT SEEDING MAY BE PERFORMED IN THE SPRING PRIOR TO JULY 1 AND IN BETWEEN AUGUST 1 AND OCTOBER 15. PERMANENT SEEDING AT OTHER TIMES SHALL BE APPROVED AND SHALL ONLY BE ALLOWED WITH AN APPROVED MULCHING AND IRRIGATION PROGRAM.

EROSION AND SEDIMENT CONTROL REQUIREMENTS

PART 1 – GENERAL

1.01 SUMMARY

A. FURNISH, INSTALL, AND MAINTAIN TEMPORARY AND PERMANENT EROSION AND SEDIMENT CONTROL MEASURES, SUCH AS, BUT NOT NECESSARILY LIMITED TO, STRAW BALE AND SILT FENCE BARRIERS, RIPRAP, VEHICLE TRACKING PADS, DIVERSION CHANNELS AND BERMS, CHECK DAMS, STRATEGICALLY LOCATED STOCKPILES, SEDIMENT BASINS, MULCH, AND SEED MIX (HEREINAFTER "CONTROL MEASURES") ADEQUATE TO PREVENT THE CONVEYANCE OF EROSION PRODUCTS (E.G. SOIL, MULCH, SOD) OFF SITE, OR INTO ENVIRONMENTALLY SENSITIVE AREAS, OR INTO AREAS WHERE WORK WILL BE ADVERSELY IMPACTED. ENVIRONMENTALLY SENSITIVE AREAS INCLUDE, BUT ARE NOT NECESSARILY LIMITED TO, WETLANDS, TRIBUTARIES TO WETLANDS, WETLAND BUFFER ZONES, INTERMITTENT AND PERENNIAL STREAMS / RIVERS, AND THEIR ATTENDANT BUFFER ZONES.

ALL METHODS AND MATERIALS USED FOR EROSION CONTROL SHALL CONFORM TO THE REQUIREMENTS SET FORTH IN "EROSION AND SEDIMENT CONTROL GUIDELINES FOR URBAN AND SUBURBAN AREAS A GUIDE FOR PLANNERS, DESIGNERS, AND MUNICIPAL OFFICIALS" AS PUBLISHED BY THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF RESOURCE PROTECTION, UNLESS OTHERWISE APPROVED IN WRITING.

1. REFER TO DRAWINGS FOR LOCATION AND DETAILS OF LIMITS OF DISTURBANCE AND CONTROL MEASURES REQUIRED TO COMMENCE WORK. LIMITS OF DISTURBANCE SHALL BE MARKED WITH TAPE, SIGNS, OR ORANGE CONSTRUCTION FENCE PRIOR TO COMMENCING ANY LAND DISTURBANCE ACTIVITIES. CONTROL MEASURES WILL BE ADEQUATE ONLY FOR VEGETATION CLEARING. THE DRAWINGS ARE NOT INTENDED TO GRAPHICALLY DEPICT ALL CONTROL MEASURES THAT WILL BE REQUIRED TO MEET THE REQUIREMENTS DESCRIBED IN 1.01.A.

2. DEVISE AND EMPLOY CONTROL MEASURES THROUGHOUT THE DURATION OF PROJECT, OVER ALL AREAS DISTURBED OR UNDISTURBED BY CONSTRUCTION, AS NECESSARY TO MEET THE REQUIREMENTS DESCRIBED IN 1.01.A.

3. DEVISE AND EMPLOY TEMPORARY CONTROL MEASURES AS NECESSARY TO MEET THE REQUIREMENTS DESCRIBED IN 1.01.A, WHILE ALLOWING WORK TO PROCEED IN AN EFFICIENT, COST EFFECTIVE MANNER.

4. DEVISE, EMPLOY AND MAINTAIN CONTROL MEASURES UNTIL SUCH TIME AS THE ENTIRE SITE IS PERMANENTLY STABILIZED BY ESTABLISHED VEGETATION, FINISH LANDSCAPE MATERIALS, PAVED SURFACES, AND/OR ROOF AREA.

5. ONCE THE SITE IS PERMANENTLY STABILIZED AND CERTIFIED AS SUCH BY ENGINEER, REMOVE TEMPORARY CONTROL MEASURES WHILE PROTECTING STABILIZED SURFACES.

1.02 SUBMITTALS

A. SUBMIT PRODUCT DATA, WARRANTY, AND TEST REPORTS AS INDICATED ON THE DRAWINGS.

B. SUBMIT SKETCH SHOWING LOCATIONS OF PROPOSED STOCKPILE AREAS, CONSTRUCTION ENTRANCES AND EROSION CONTROLS IF NOT SHOWN ON THE SITE PLAN OR DIFFERENT FROM THOSE LOCATIONS SHOWN ON THE SITE PLAN.

C. A SITE SPECIFIC SEQUENCE OF CONSTRUCTION FOR EACH PORTION OF THE SITE. NO PORTION OF THE SITE SHALL EXCEED FIVE (5) ACRES.

1.03 QUALITY ASSURANCE

A. COMPLY WITH GOVERNING CODES AND REGULATIONS. PROVIDE PRODUCTS FROM ACCEPTABLE MANUFACTURERS. USE EXPERIENCED INSTALLERS. DELIVER, HANDLE, AND STORE MATERIALS IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

B. CONFORM TO CONDITIONS OF APPROVAL ISSUED BY REGULATORY AGENCIES INCLUDING, BUT NOT NECESSARILY LIMITED TO, LOCAL PLANNING BOARD, CONSERVATION COMMISSION, CITY COUNCIL, BOARD OF HEALTH, PUBLIC WORKS / HIGHWAY DEPARTMENT, STATE ENVIRONMENTAL PROTECTION DEPARTMENT, AND U.S. GOVERNMENT, ENVIRONMENTAL PROTECTION AGENCY. WHERE CONDITIONS OF REGULATORY APPROVAL DIFFER FROM REQUIREMENTS CONTAINED HEREIN OR ON THE DRAWINGS, COMPLY WITH THE MORE STRINGENT REQUIREMENT.

PART 2 – PRODUCTS

2.01 MATERIALS

A. STRAW BALES: WEED FREE DRY GRASS OR STRAW, MACHINE BOUND WITH JUTE OR WIRE, APPROXIMATE SIZE EACH BALE 42" X 16" X 16". EACH BALE SHALL BE STAKED WITH A MINIMUM OF TWO 24" LONG HARDWOOD STAKES. NOTE: HAY SHALL NOT BE USED.

B. STRAW WATTLES: NORTH AMERICAN GREEN MODEL WS1210 OR APPROVED EQUAL.

C. SILT FENCE: NON–WOVEN, UV–RESISTANT, POLYPROPYLENE FABRIC, FLOW RATED AT 10 GPM/SF MINIMUM, GRAB TENSILE RATED AT 124 POUNDS MINIMUM, WITH INTEGRAL STAKE LOOPS, AND HARDWOOD STAKES. USE NO. 2130 BY AMOCO FABRICS & FIBERS, OR APPROVED EQUAL.

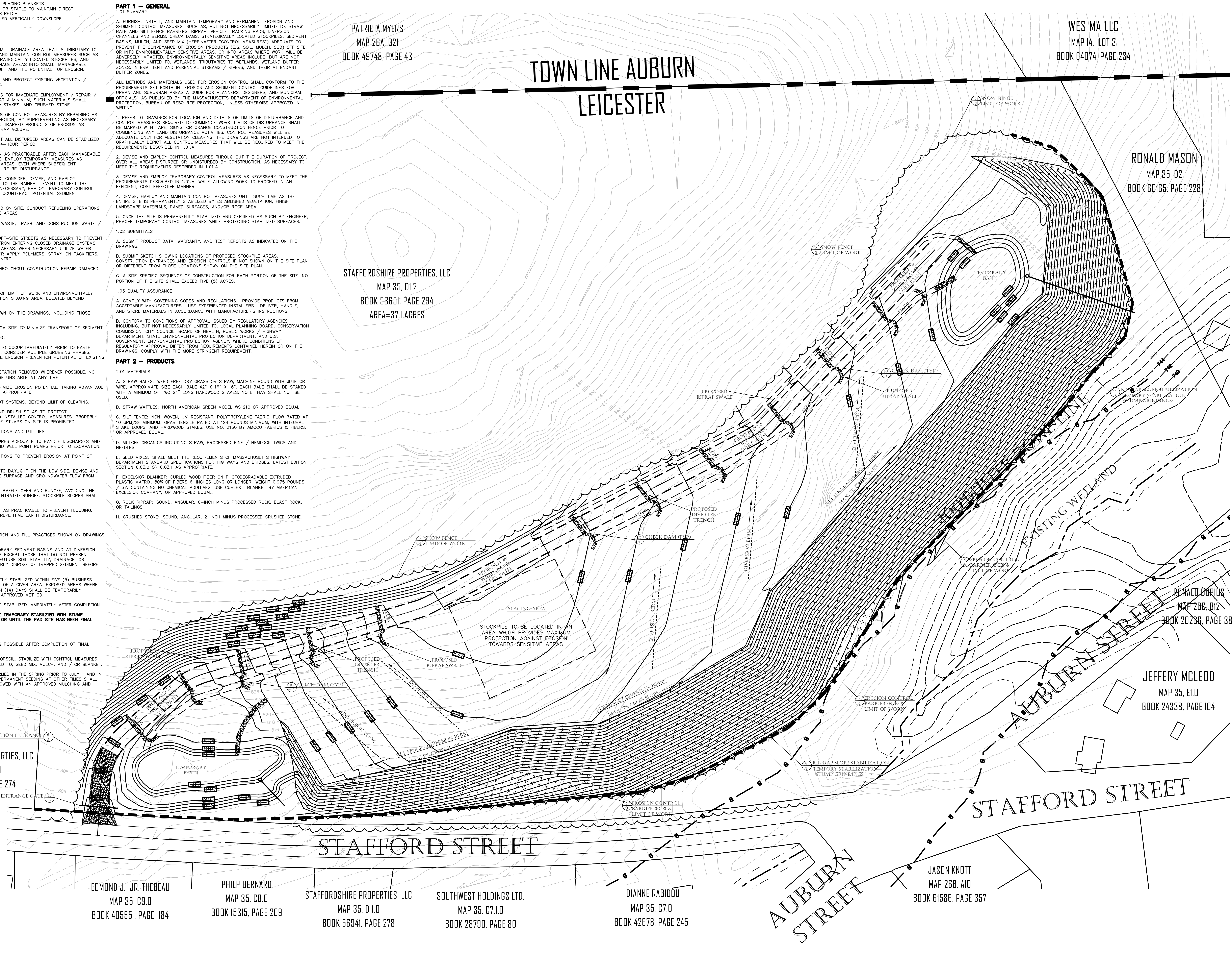
D. MULCH: ORGANICS INCLUDING STRAW, PROCESSED PINE / HEMLOCK TWIGS AND NEEDLES.

E. SEED MIXES: SHALL MEET THE REQUIREMENTS OF MASSACHUSETTS HIGHWAY DEPARTMENT STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES, LATEST EDITION SECTION 6.03.0 OR 6.03.1 AS APPROPRIATE.

F. EXCELSIOR BLANKET: CURLED WOOD FIBER ON PHOTODEGRADABLE EXTRUDED PLASTIC MATRIX, 80% OF FIBERS 6–INCHES LONG OR LONGER, WEIGHT 0.975 POUNDS / SY, CONTAINING NO CHEMICAL ADDITIVES. USE CURLEX I BLANKET BY AMERICAN EXCELSIOR COMPANY, OR APPROVED EQUAL.

G. ROCK RIPRAP: SOUND, ANGULAR, 6–INCH MINUS PROCESSED ROCK, BLAST ROCK, OR TAILINGS.

H. CRUSHED STONE: SOUND, ANGULAR, 2–INCH MINUS PROCESSED CRUSHED STONE.



P.E.	P.L.S.

APPROVAL UNDER SITE PLAN REVIEW.
LEICESTER PLANNING BOARD

BEING A MAJORITY

____

____

____

____

____

APPROVAL DATE:________________

ENDORSEMENT DATE:________________

REVISIONS

REV.	DATE	DESCRIPTION

PROJECT NO.	21–301
DESIGNED BY	PML
CHECKED BY	SB
DATE	3/3/22
CAD FILE	21–301 SPECIAL PERMIT

GRAPHIC SCALE

60 0 30 60 120

(IN FEET)
1 inch = 60 feet

PREPARED BY:
TAUPER
Engineering & Survey, Inc.
710 MAIN STREET
OXFORD, MA 01537
P:(508) 987-8713 F:(508) 987-8714

SHEET TITLE

GRADING PLAN

SPECIAL PERMIT PLAN
at
STAFFORD STREET

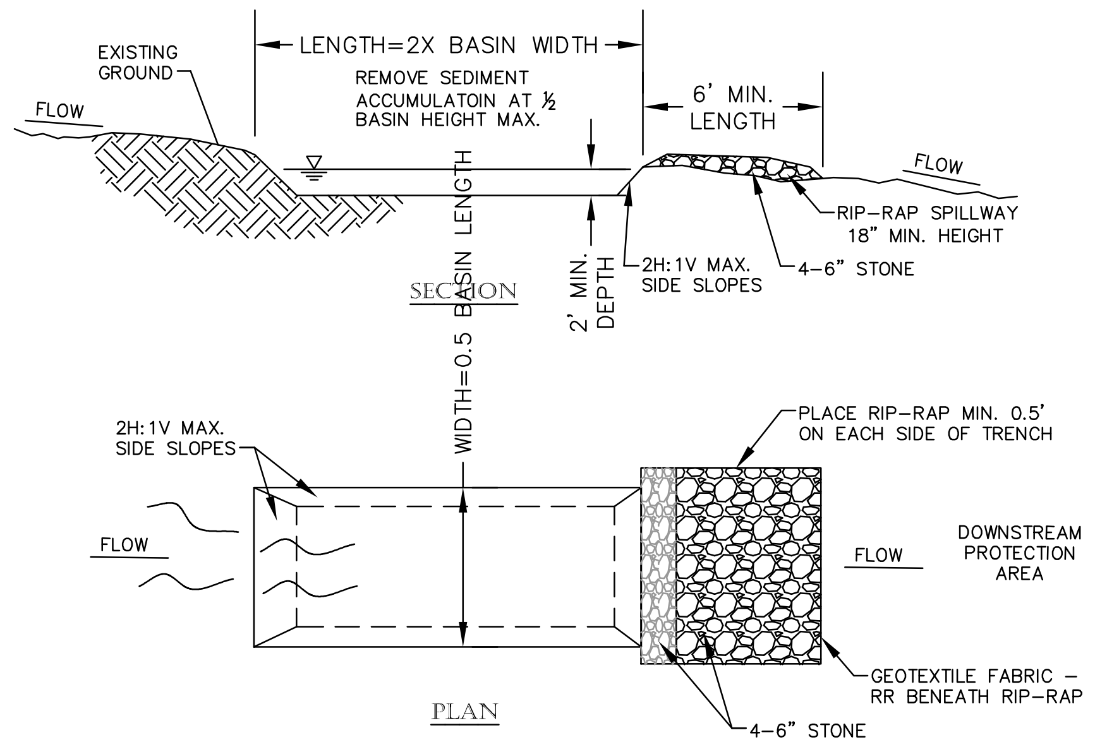
LEICESTER, MA
PREPARED FOR
STAFFORDSHIRE

SHEET NO.

C–3.0

Y:\Land Projects\Land Projects 2021\StaffordShire\21-301 SPEICAL PERMIT-SITE PLAN STAFFORD ST LEICESTER.dwg

Y:\Land Projects\Land Projects 2021\StaffordShire\21-301 SPECIAL PERMIT-SITE PLAN STAFFORD ST LEICESTER.dwg



① RIP-RAP SLOPE STABILIZATION

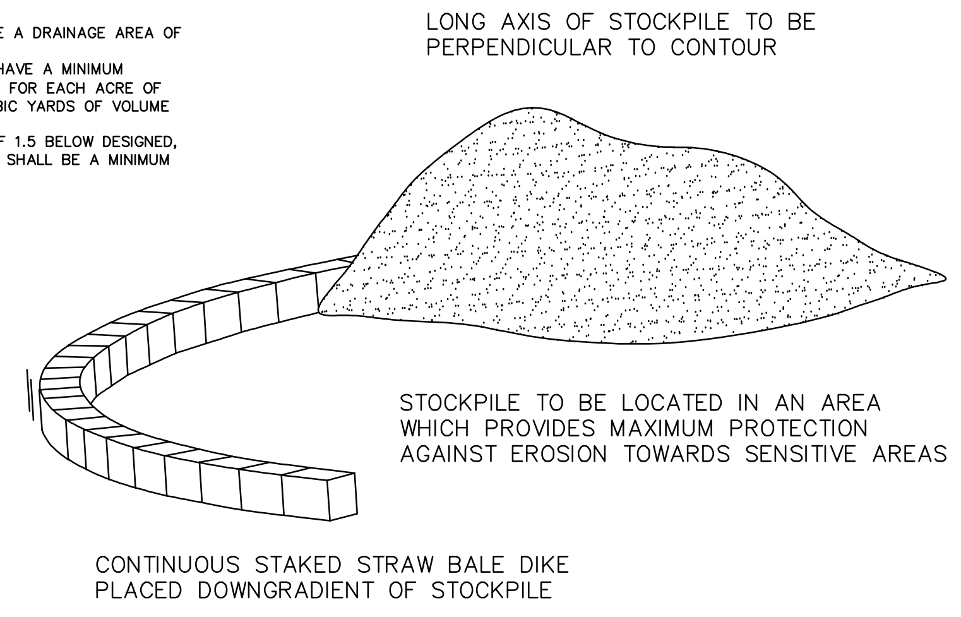
N.T.S.

NOTES:

[1] TEMPORARY SEDIMENT TRAPS SHALL HAVE A DRAINAGE AREA OF NOT MORE THAN 5 ACRES.

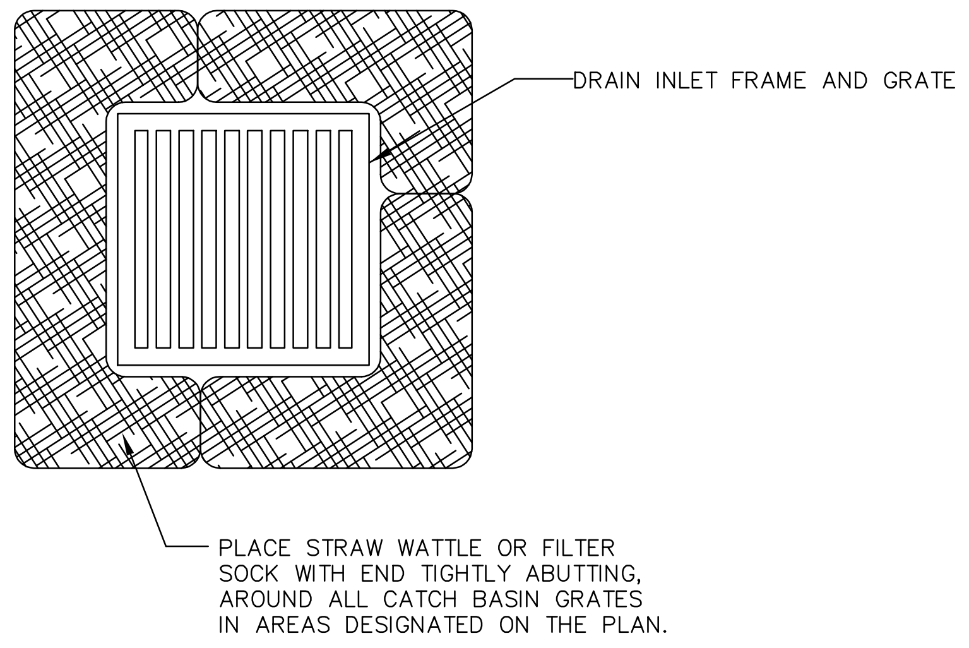
[2] THE TEMPORARY SEDIMENT TRAP SHALL HAVE A MINIMUM VOLUME BASED ON 1/2 INCH OF STORAGE FOR EACH ACRE OF CONTRIBUTING DRAINAGE AREA OR 67 CUBIC YARDS OF VOLUME FOR EACH ACRE OF DRAINAGE AREA.

[3] SPILLWAY DEPTH SHALL BE A MINIMUM OF 1.5 BELOW DESIGNED, SETTLED TO OF EMBANKMENT. FREEBOARD SHALL BE A MINIMUM OF 0.5 FOOT.



② TEMPORARY STOCKPILE

N.T.S.



③ CATCH BASIN STRAW WATTLE/FILTER SOCK

N.T.S.

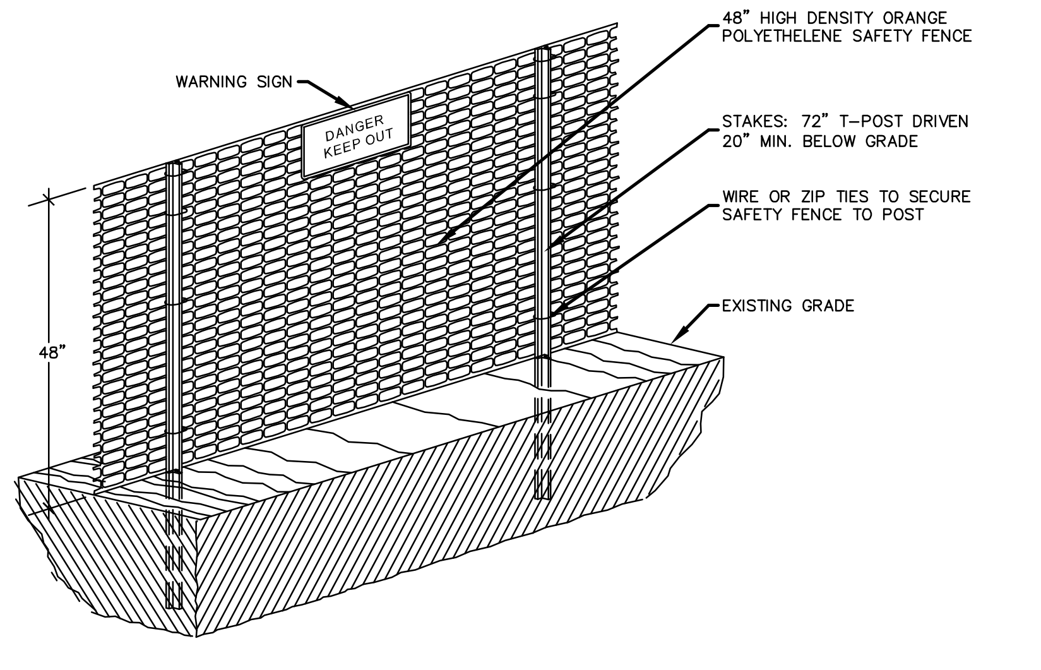
NOTES:

[1] ALL ACTIVE CONSTRUCTION AREAS SHALL BE PROTECTED PER PLAN.

[2] SAFETY FENCE SHALL BE FASTENED SECURELY TO T-POSTS.

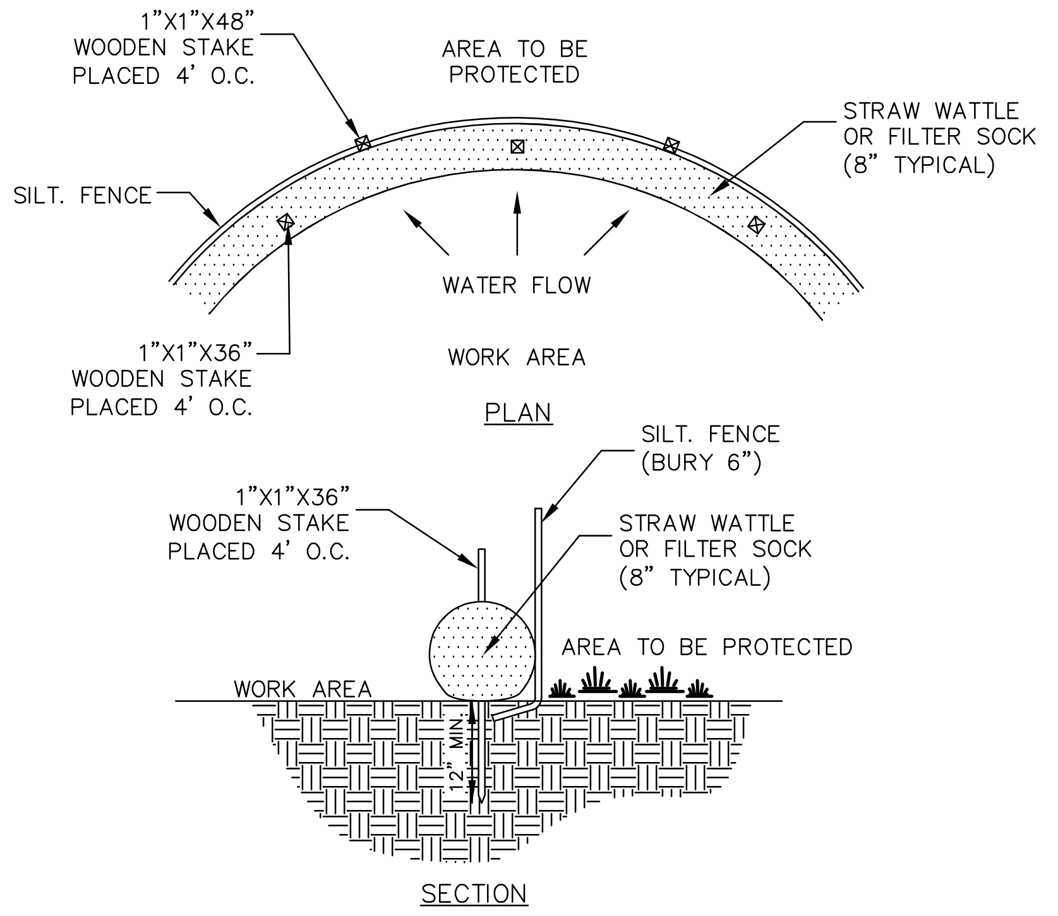
[3] FENCING MUST REMAIN IN PLACE DURING ALL PHASES OF CONSTRUCTION; ANY CHANGE OF THE SAFETY FENCE MUST BE APPROVED.

[4] "DANGER KEEP OUT" SIGNS TO BE SPACED AT 100 FOOT INTERVALS.



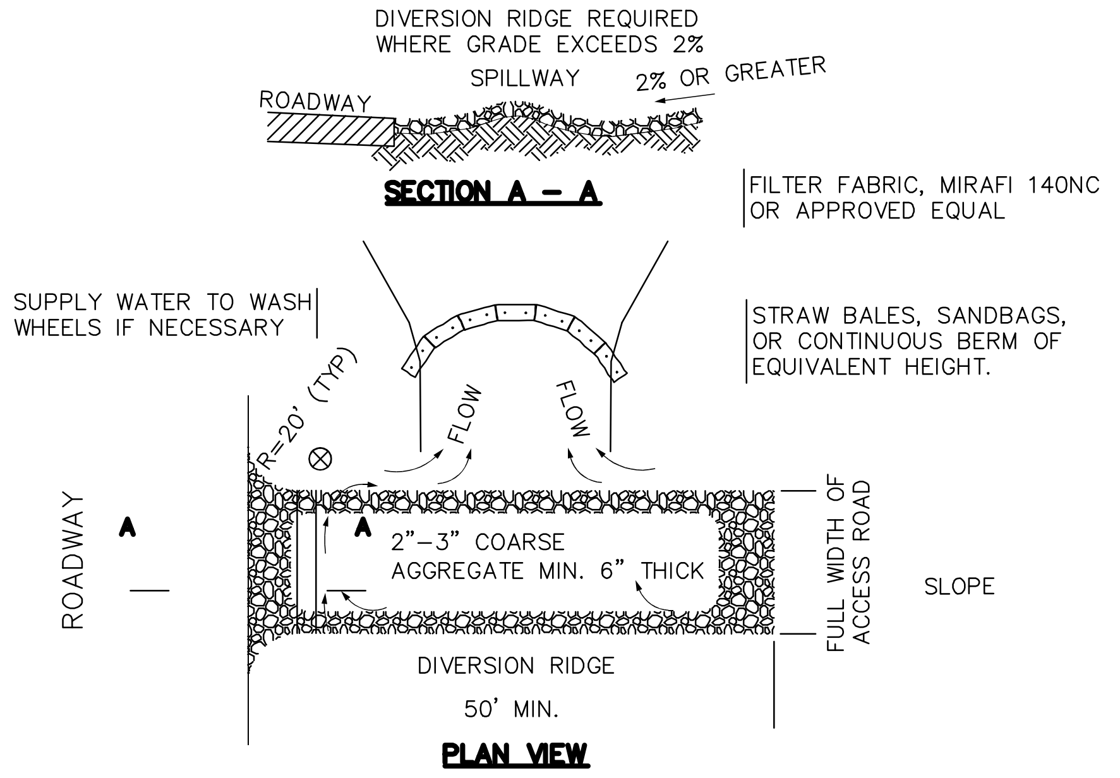
④ CONSTRUCTION SAFETY FENCE

N.T.S.



⑤ EROSION CONTROL BARRIER (ECB)

N.T.S.



NOTES:

[1] THE ENTRANCE SHALL BE MAINTAINED IN A CONDITION THAT WILL PREVENT TRACKING OR FLOWING OF SEDIMENT ONTO PUBLIC RIGHT-OF-WAYS. THIS MAY REQUIRE TOP DRESSING, REPAIR AND/OR CLEANOUT OF ANY MEASURES USED TO TRAP SEDIMENT.

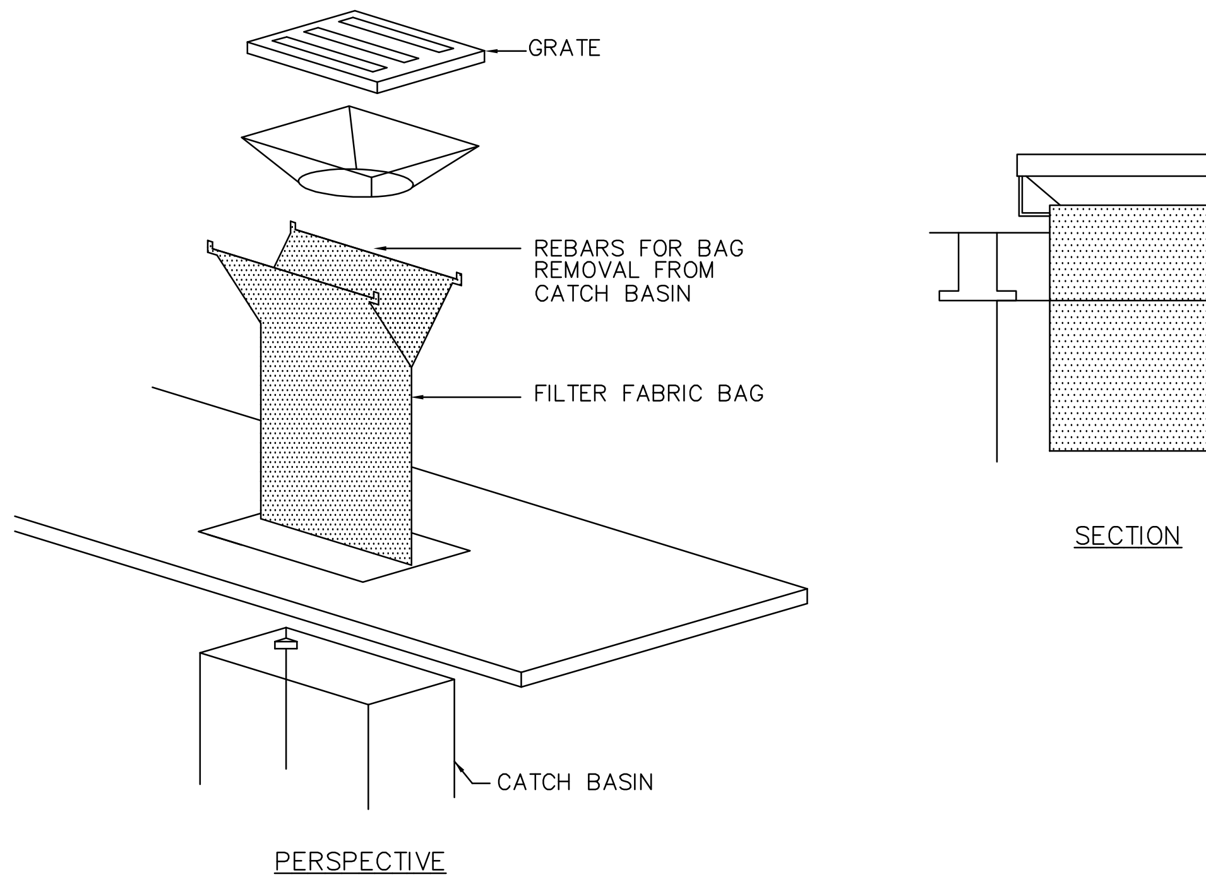
[2] WHEN NECESSARY, WHEELS SHALL BE CLEANED PRIOR TO ENTRANCE ONTO PUBLIC RIGHT-OF-WAY.

[3] WHEN WASHING IS REQUIRED, IT SHALL BE DONE ON AREA STABILIZED WITH CRUSHED STONE THAT DRAINS INTO AN APPROVED SEDIMENT TRAP OR SEDIMENT BASIN.

[4] USE SANDBAGS, STRAW BALES OR OTHER APPROVED METHODS TO CHANNELIZE RUNOFF TO BASIN AS REQUIRED.

⑥ CONSTRUCTION ENTRANCE

N.T.S.



NOTES:

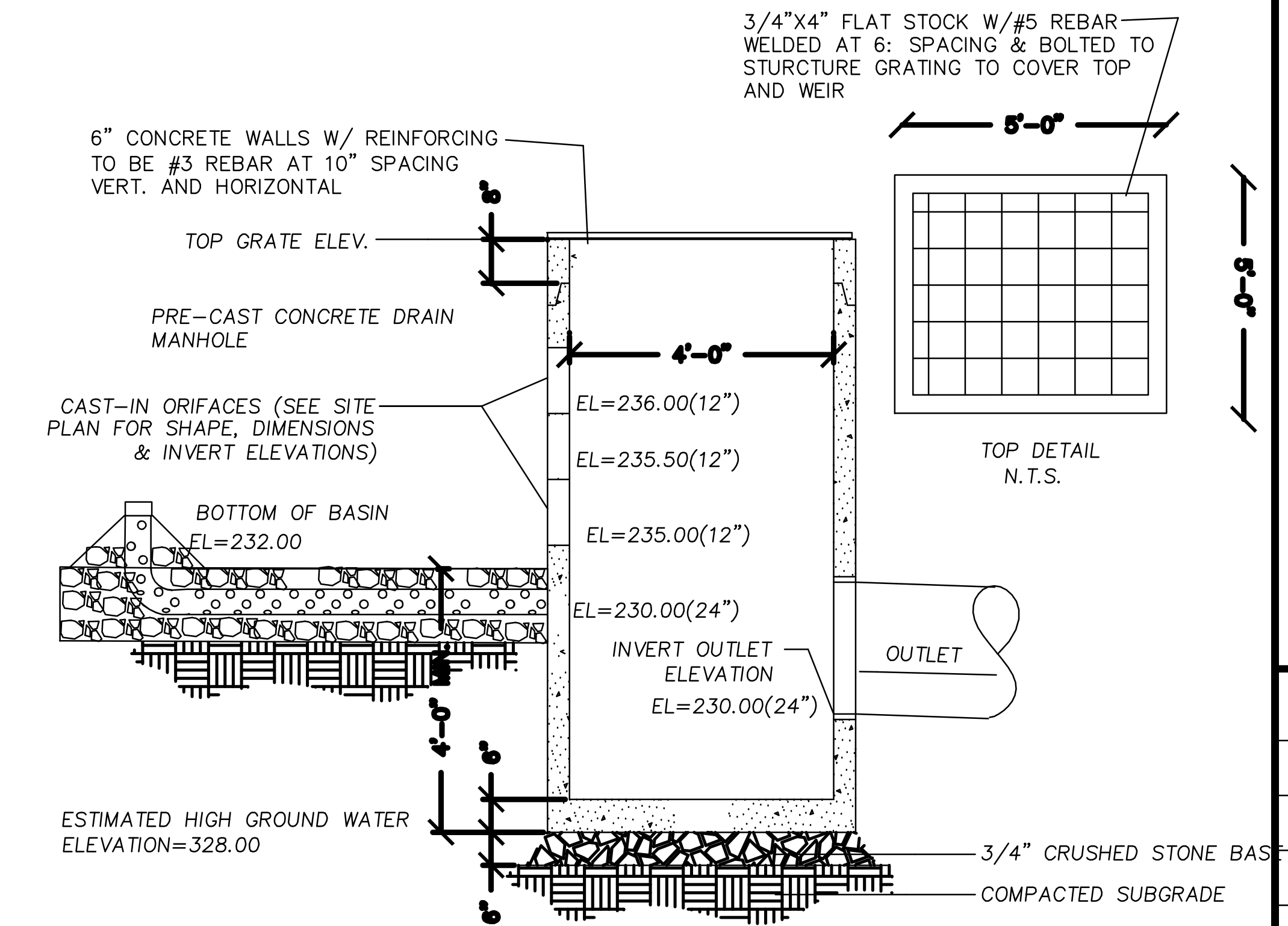
[1] TO BE SILTSTACK BY ATLANTIC CONSTRUCTION FABRICS, INC., OR APPROVED EQUAL.

[2] TO BE INSTALLED IMMEDIATELY FOLLOWING THE INSTALLATION OF CATCH BASIN STRUCTURE AND REMAIN UNTIL FINISH COURSE IS PLACED.

[3] FILTER BAG SHALL BE MAINTAINED AND CLEANED AS NEEDED.

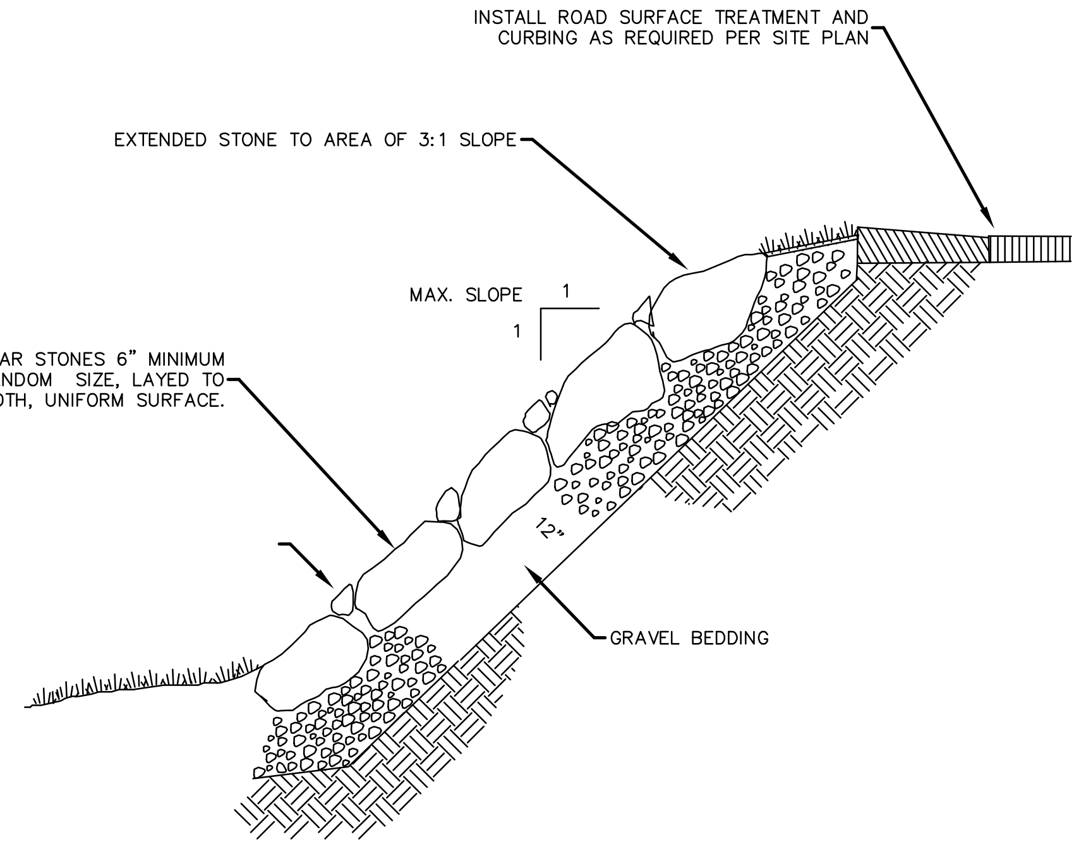
⑦ CATCH BASIN FILTER BAG

N.T.S.



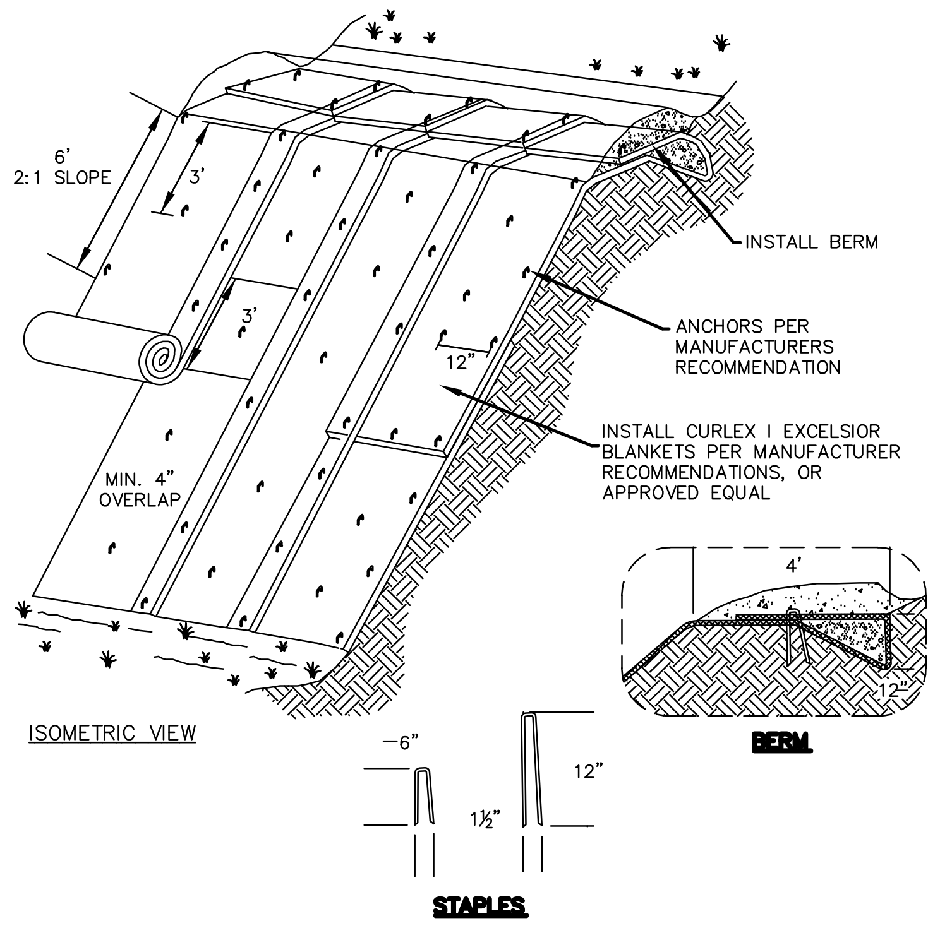
⑫ OUTLET CONTROL STRUCTURE

NOT TO SCALE



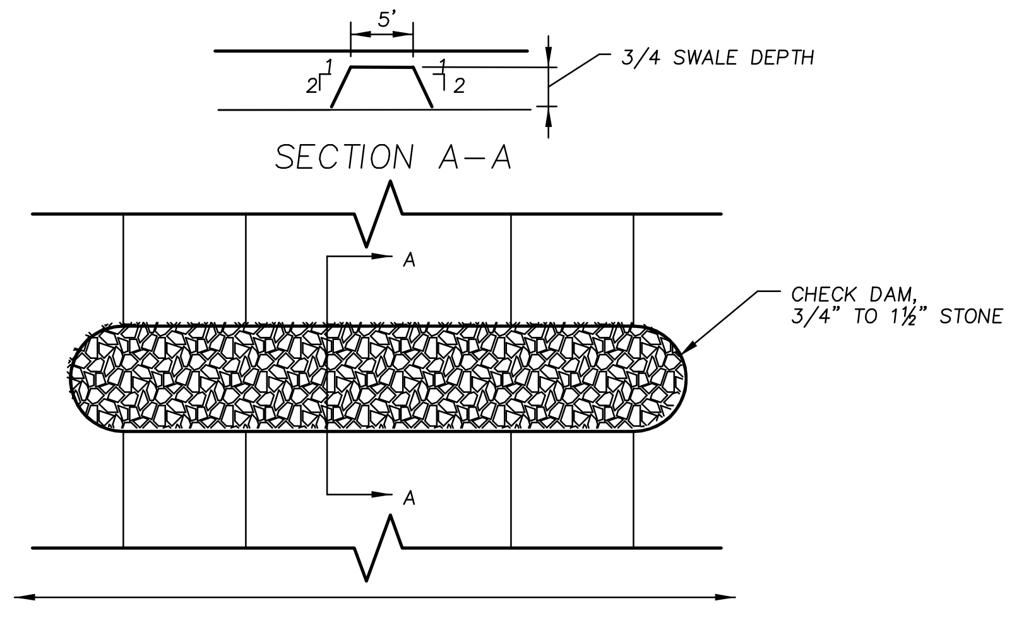
⑧ RIP-RAP SLOPE STABILIZATION

N.T.S.



⑨ EROSION CONTROL BLANKET SLOPE STABILIZATION

N.T.S.



GRASSED SWALE

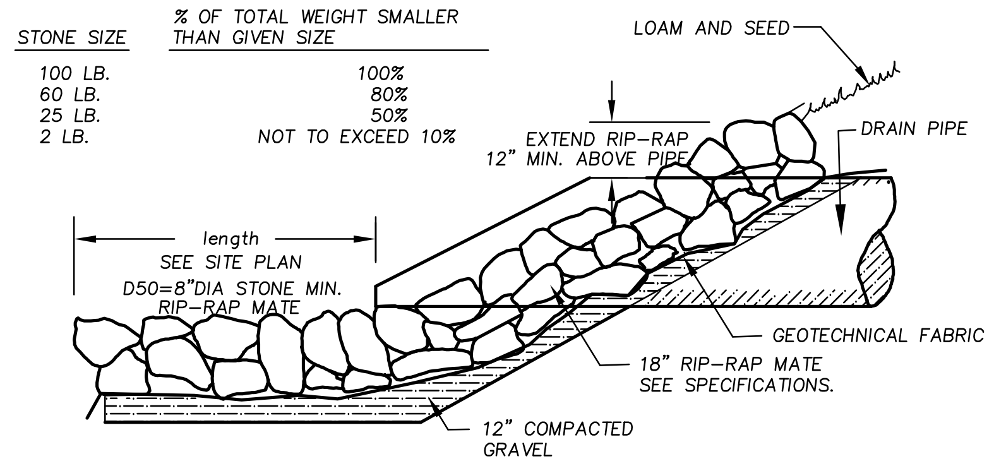
⑩ CHECK DAM

N.T.S.

	Pipe Diameter	APRON Length L (FT.)	WIDTH W1 (FT.)	WIDTH W2 (FT.)
FES#1	36"	11'	6'	7.4'
FES#2	24"	8.5'	9'	10.85'

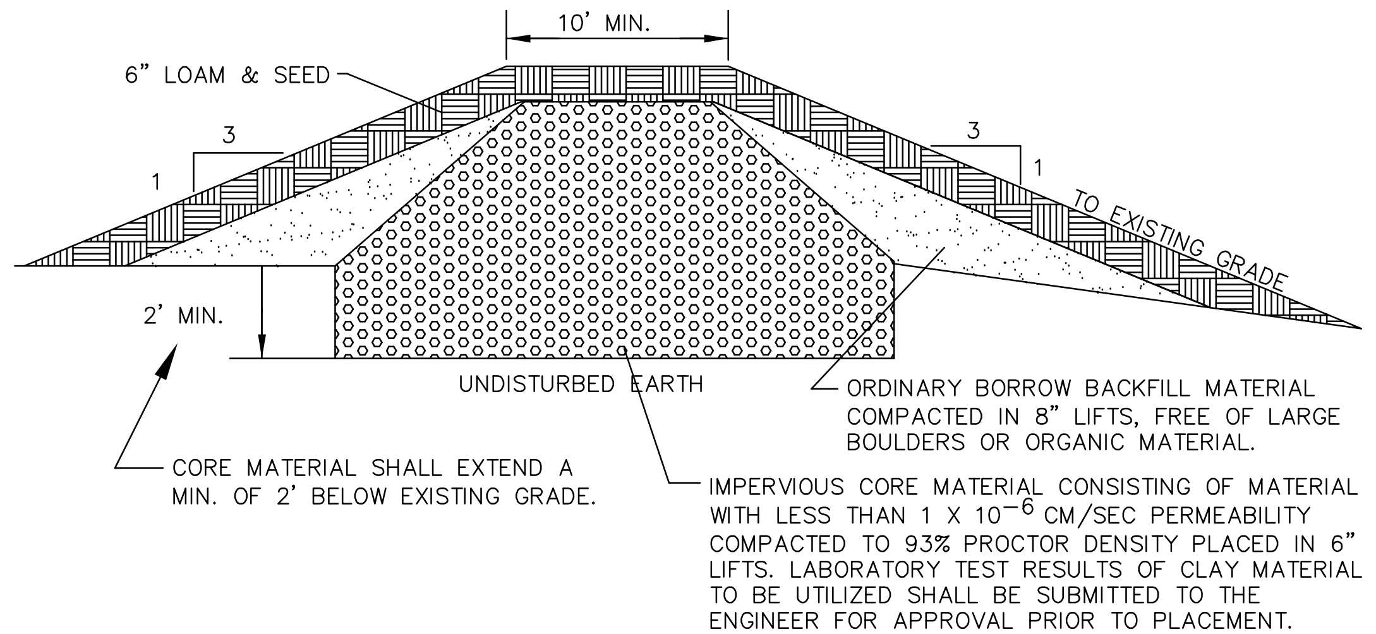
RIP-RAP SPECIFICATIONS

STONE SIZE	% OF TOTAL WEIGHT SMALLER THAN GIVEN SIZE
100 LB.	100%
60 LB.	80%
25 LB.	50%
2 LB.	NOT TO EXCEED 10%



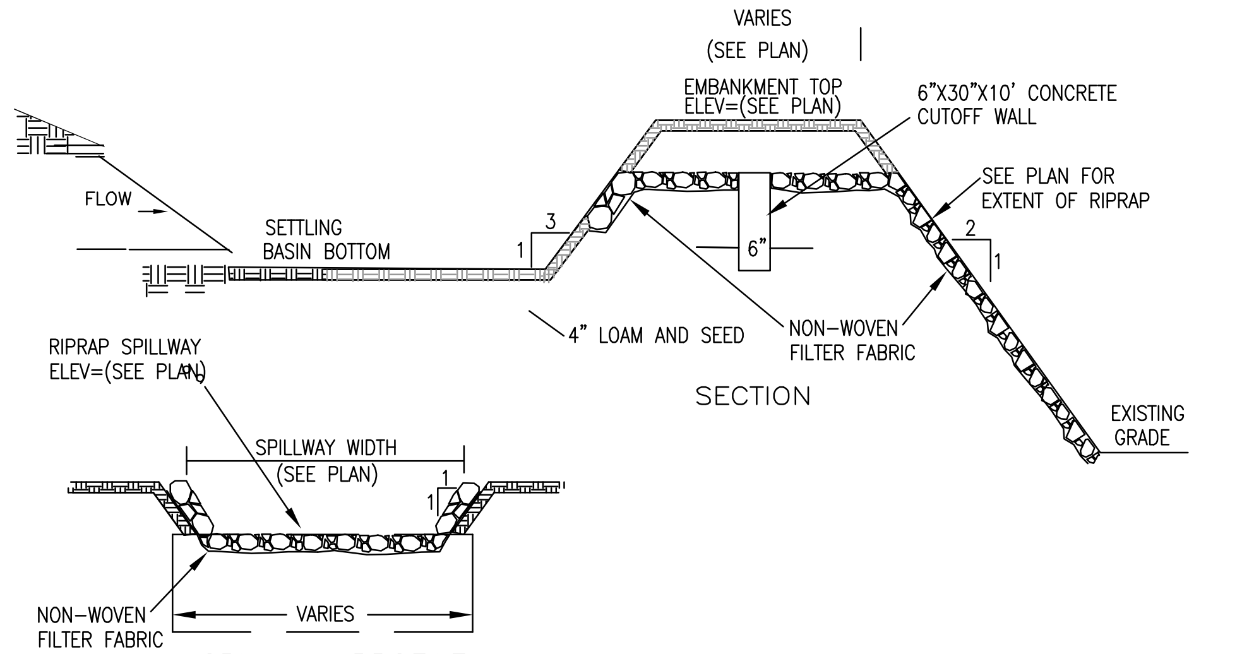
⑪ FLARED END RIP RAP OUTLET

NOT TO SCALE



⑬ DETENTION BASIN DETAIL

NOT TO SCALE



⑭ LEVEL SPREADER & SETTLING BASIN

P.E.	P.L.S.

APPROVAL UNDER SITE PLAN REVIEW.
LEICESTER PLANNING BOARD

BEING A MAJORITY

APPROVAL DATE: ____________

ENDORSEMENT DATE: ____________

REVISIONS

REV.	DATE	DESCRIPTION

PROJECT NO.	21-301
DESIGNED BY	PML
CHECKED BY	SB
DATE	3/3/22
CAD FILE	21-301 SPECIAL PERMIT

PREPARED BY:
TAUPER
Engineering & Survey, Inc.
710 MAIN STREET
OXFORD, MA 01537
P:(508) 987-8713 F:(508) 987-8714

SHEET TITLE

DETAIL SHEET

SPECIAL PERMIT PLAN
at
STAFFORD STREET

LEICESTER, MA
PREPARED FOR
STAFFORDSHIRE

SHEET NO.

C-4.0

MassDEP - Bureau of Waste Site Cleanup

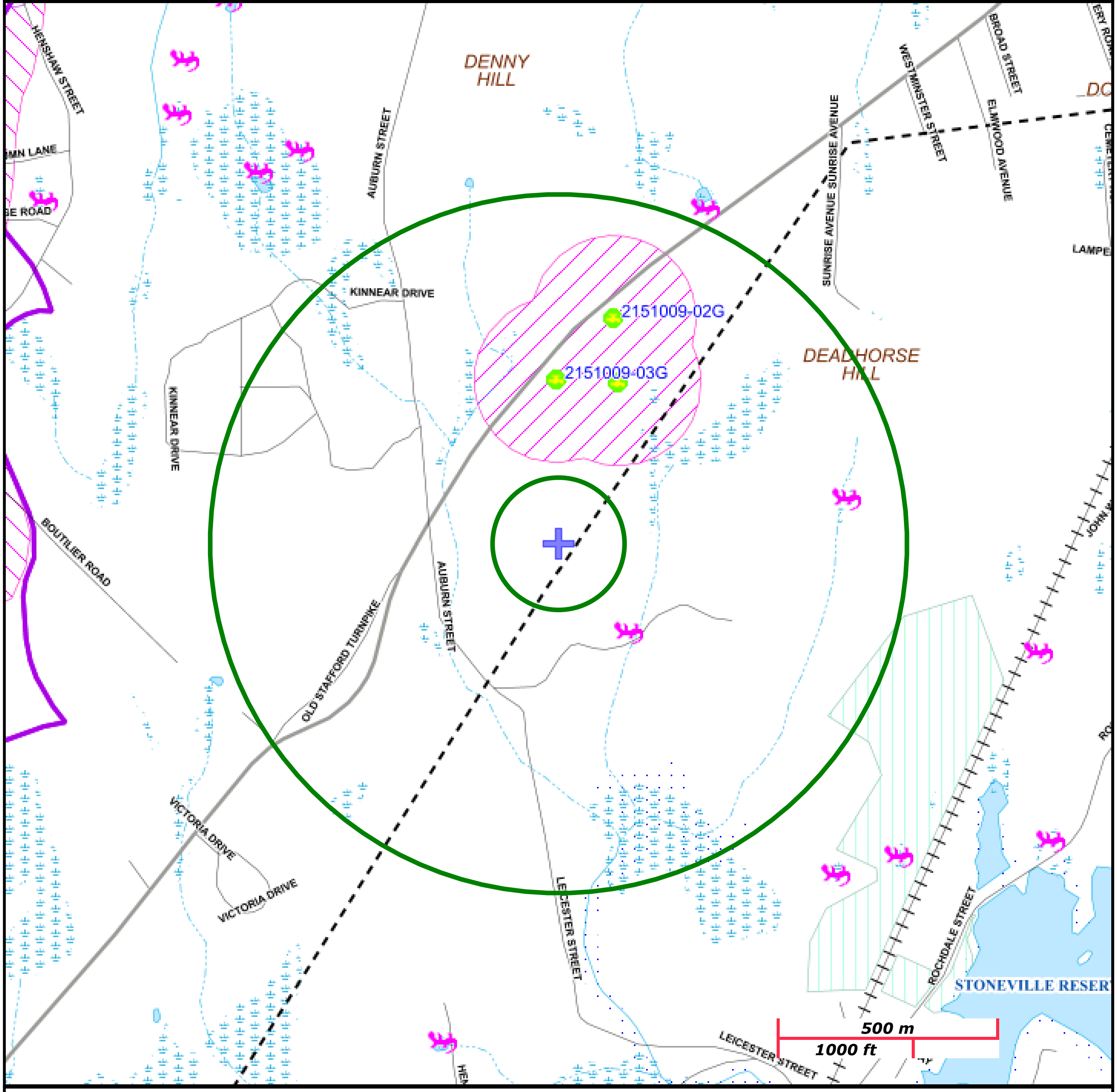
Phase 1 Site Assessment Map: 500 feet & 0.5 Mile Radii

Site Information:
STAFFORD STREET
0 STAFFORD STREET LEICESTER, MA

NAD83 UTM Meters:
4677955mN , 262774mE (Zone: 19)
March 8, 2022

The information shown is the best available at the date of printing. However, it may be incomplete. The responsible party and LSP are ultimately responsible for ascertaining the true conditions surrounding the site. Metadata for data layers shown on this map can be found at: https://www.mass.gov/orgs/massgis-bureau-of-geographic-information.

MassDEP
Commonwealth of Massachusetts
Department of Environmental Protection



Roads: Limited Access, Divided, Other Hwy, Major Road, Minor Road, Track, Trail

Boundaries: Town, County, DEP Region; Train; Powerline; Pipeline; Aqueduct

Basins: Major, PWS; Streams: Perennial, Intermittent, Man Made Shore, Dam

Aquifers: Medium Yield, High Yield, EPA Sole Source.....

Non Potential Drinking Water Source Area: Medium, High (Yield)...

PWS Protection Areas: Zone II, IWPA, Zone A ....

Hydrography: Open Water, PWS Reservoir, Tidal Flat ....

Wetlands: Freshwater, Saltwater, Cranberry Bog ....

FEMA 100yr Floodplain; Protected Open Space; ACEC ....

Est. Rare Wetland Wildlife Hab; Vernal Pool: Cert., Potential

Solid Waste Landfill; PWS: Com.GW,SW, Emerg.,Non-Com.

ATTACHMENT B
ACCEPTANCE CRITERIA TABLE

Lighthouse Environmental Management, LLC
184 Stone Street, Clinton, MA
(617) 699-5245

Parker Environmental Corporation
97 Walnut Street, Clinton, MA
(978) 273-4263

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria
MCP Polychlorinated Biphenyls			
PCBs, Total	mg/kg	1	<0.1
Petroleum Hydrocarbons			
Total Petroleum Hydrocarbons	mg/kg	1,000	<500
OR - Total EPH Fractions			
C9-C18 Aliphatic - EPH	mg/kg	1,000	<100
C19-C36 Aliphatic - EPH	mg/kg	3,000	<300
C11-C22 Aromatic - EPH	mg/kg	1,000	<100
C5-C8 Aliphatic - VPH	mg/kg	100	<10
C9-C12 Aliphatic - VPH	mg/kg	1,000	<100
C9-C10 Aromatic - VPH	mg/kg	100	<10
General Chemistry			
Specific Conductance	umhos/cm	NA	<4,000
pH	SU	NA	5-11
Flash Point	deg F	NA	>200
Cyanide, Reactive	mg/kg	NA	<500
Sulfide, Reactive	mg/kg	NA	<250
Ammenable Cyanide (1)		30	<3
Asbestos (1)		1%	ND
Dioxins (1)	mg/kg	0.000002	<0.0000002
Perchlorate Compounds (1)	mg/kg	0.1	<0.01
Per- and Polyfluoroalkyl Substances (PFAS) (1)			
PEFLUORODECANOIC ACID (PFDA)	mg/kg	0.0003	<0.00003
PERFLUOROHEPTANOIC ACID (PFHpA)	mg/kg	0.0003	<0.00003
PERFLUOROHEXANESULFONIC ACID (PFHxS)	mg/kg	0.0003	<0.00003
PERFLUORONONANOIC ACID (PFNA)	mg/kg	0.0003	<0.00003
PERFLUOROOCTANESULFONIC ACID (PFOS)	mg/kg	0.0003	<0.00003
PERFLUOROOCTANOIC ACID (PFOA)	mg/kg	0.0003	<0.00003

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria
MCP Semivolatile Organic Compounds			
1,1-Biphenyl	mg/kg	0.05	<0.005
Acenaphthene	mg/kg	4	<4
1,2,4-Trichlorobenzene	mg/kg	2	<0.2
Hexachlorobenzene	mg/kg	0.7	<0.07
Bis(2-chloroethyl)ether	mg/kg	0.7	<0.07
2-Chloronaphthalene	mg/kg	1000	<100
1,2-Dichlorobenzene	mg/kg	9	<0.9
1,3-Dichlorobenzene	mg/kg	3	<0.3
1,4-Dichlorobenzene	mg/kg	0.7	<0.07
3,3'-Dichlorobenzidine	mg/kg	3	<0.3
2,4-Dinitrotoluene	mg/kg	0.7	<0.07
2,6-Dinitrotoluene	mg/kg	100	<10
Azobenzene	mg/kg	50	<5
Fluoranthene	mg/kg	1000	<40
4-Bromophenyl phenyl ether	mg/kg	100	<10
Bis(2-chloroisopropyl)ether	mg/kg	0.7	<0.07
Bis(2-chloroethoxy)methane	mg/kg	500	<50
Hexachlorobutadiene	mg/kg	30	<3
Hexachloroethane	mg/kg	0.7	<0.07
Isophorone	mg/kg	100	<10
Naphthalene	mg/kg	4	<4
Nitrobenzene	mg/kg	500	<50
Bis(2-ethylhexyl)phthalate	mg/kg	90	<9
Butyl benzyl phthalate	mg/kg	100	<10
Di-n-butylphthalate	mg/kg	50	<5
Di-n-octylphthalate	mg/kg	1000	<100
Diethyl phthalate	mg/kg	10	<1
Dimethyl phthalate	mg/kg	0.7	<0.07
Benzo(a)anthracene	mg/kg	7	<7
Benzo(a)pyrene	mg/kg	2	<2
Benzo(b)fluoranthene	mg/kg	7	<7
Benzo(k)fluoranthene	mg/kg	70	<10
Chrysene	mg/kg	70	<20
Acenaphthylene	mg/kg	1	<1
Anthracene	mg/kg	1000	<10
Benzo(ghi)perylene	mg/kg	1000	<10
Fluorene	mg/kg	1000	<10
Phenanthrene	mg/kg	10	<10
Dibenzo(a,h)anthracene	mg/kg	0.7	<0.7
Indeno(1,2,3-cd)pyrene	mg/kg	7	<7
Pyrene	mg/kg	1000	<40
Aniline	mg/kg	1000	<100
4-Chloroaniline	mg/kg	1	<0.1
Dibenzofuran	mg/kg	100	<10
2-Methylnaphthalene	mg/kg	0.7	<0.7
Acetophenone	mg/kg	1000	<100
2,4,6-Trichlorophenol	mg/kg	0.7	<0.07

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria
MCP Semivolatile Organic Compounds			
2-Chlorophenol	mg/kg	0.7	<0.07
2,4-Dichlorophenol	mg/kg	0.7	<0.07
2,4-Dimethylphenol	mg/kg	0.7	<0.07
2-Nitrophenol	mg/kg	100	<10
4-Nitrophenol	mg/kg	100	<10
2,4-Dinitrophenol	mg/kg	3	<0.3
Pentachlorophenol	mg/kg	3	<0.3
Phenol	mg/kg	1	<0.1
2-Methylphenol	mg/kg	500	<50
3-Methylphenol/4-Methylphenol	mg/kg	500	<50
2,4,5-Trichlorophenol	mg/kg	4	<0.4
MCP Total Metals			
Antimony	mg/kg	20	<10
Arsenic, Total	mg/kg	20	<20
Arsenic, Total* Naturally occurring	mg/kg	NA	<59
Barium, Total	mg/kg	1,000	<375
Beryllium	mg/kg	90	<4
Cadmium, Total	mg/kg	70	<20
Chromium, Total	mg/kg	100	<100
Chromium, (Tri)	mg/kg	1,000	<225
Chromium, (Hex)	mg/kg	100	<100
Copper	mg/kg	NE	<300
Lead, Total	mg/kg	200	<200
Mercury, Total	mg/kg	20	<3
Nickel	mg/kg	600	<150
Selenium, Total	mg/kg	400	<5
Silver, Total	mg/kg	100	<6
Thallium	mg/kg	8	<6
Vanadium	mg/kg	400	<225
Zinc	mg/kg	1,000	<500
MCP Volatile Organic Compounds			
Methylene chloride	mg/kg	0.1	<0.01
1,1-Dichloroethane	mg/kg	0.4	<0.04
Chloroform	mg/kg	0.2	<0.02
Carbon tetrachloride	mg/kg	5	<0.05
1,2-Dichloropropane	mg/kg	0.1	<0.01
Dibromochloromethane	mg/kg	0.005	<0.0005
1,1,2-Trichloroethane	mg/kg	0.1	<0.01
Tetrachloroethene	mg/kg	1	<0.1
Chlorobenzene	mg/kg	1	<0.1
Trichlorofluoromethane	mg/kg	1,000	<100
1,2-Dichloroethane	mg/kg	0.1	<0.01
1,1,1-Trichloroethane	mg/kg	30	<3
Bromodichloromethane	mg/kg	0.1	<0.01
trans-1,3-Dichloropropene	mg/kg	0.01	<0.001
cis-1,3-Dichloropropene	mg/kg	0.01	<0.001
1,3-Dichloropropene, Total	mg/kg	0.01	<0.001
1,1-Dichloropropene	mg/kg	0.01	<0.001

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria
MCP Volatile Organic Compounds			
Bromoform	mg/kg	0.1	<0.01
1,1,2,2-Tetrachloroethane	mg/kg	0.005	<0.0005
Benzene	mg/kg	2	<0.2
Toluene	mg/kg	30	<3
Ethylbenzene	mg/kg	40	<4
Chloromethane	mg/kg	100	<10
Bromomethane	mg/kg	0.5	<0.05
Vinyl chloride	mg/kg	0.7	<0.07
Chloroethane	mg/kg	100	<10
1,1-Dichloroethene	mg/kg	3	<0.3
trans-1,2-Dichloroethene	mg/kg	1	<0.01
Trichloroethene	mg/kg	0.3	<0.03
1,2-Dichlorobenzene	mg/kg	9	<0.9
1,3-Dichlorobenzene	mg/kg	3	<0.3
1,4-Dichlorobenzene	mg/kg	0.7	<0.07
Methyl tert butyl ether	mg/kg	0.1	<0.01
p/m-Xylene	mg/kg	100	<10
o-Xylene	mg/kg	100	<10
Xylenes, Total	mg/kg	100	<10
cis-1,2-Dichloroethene	mg/kg	0.1	<0.01
1,2-Dichloroethene, Total	mg/kg	0.3	<0.03
Dibromomethane	mg/kg	500	<50
1,2,3-Trichloropropane	mg/kg	100	<10
Styrene	mg/kg	3	<0.3
Dichlorodifluoromethane	mg/kg	1000	<100
Acetone	mg/kg	6	<0.6
Carbon disulfide	mg/kg	100	<10
Methyl ethyl ketone	mg/kg	4	<0.4
Methyl isobutyl ketone	mg/kg	0.4	<0.04
2-Hexanone	mg/kg	100	<10
Bromochloromethane	mg/kg	100	<10
Tetrahydrofuran	mg/kg	500	<50
2,2-Dichloropropane	mg/kg	0.1	<0.01
1,2-Dibromoethane	mg/kg	0.1	<0.01
1,3-Dichloropropane	mg/kg	500	<50
1,1,1,2-Tetrachloroethane	mg/kg	0.1	<0.01
Bromobenzene	mg/kg	100	<10
tert-Butylbenzene	mg/kg	100	<10
o-Chlorotoluene	mg/kg	100	<10
p-Chlorotoluene	mg/kg	100	<10
1,2-Dibromo-3-chloropropane	mg/kg	10	<1
Hexachlorobutadiene	mg/kg	30	<3

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria
MCP Volatile Organic Compounds			
Isopropylbenzene	mg/kg	1000	<100
p-Isopropyltoluene	mg/kg	100	<10
Naphthalene	mg/kg	4	<4
n-Propylbenzene	mg/kg	100	<10
1,2,4-Trichlorobenzene	mg/kg	2	<0.2
1,3,5-Trimethylbenzene	mg/kg	10	<1
1,2,4-Trimethylbenzene	mg/kg	1000	<100
Diethyl ether	mg/kg	100	<10
Diisopropyl Ether	mg/kg	100	<10
1,4-Dioxane	mg/kg	0.2	<0.02
Herbicides(2)			
MCPA	mg/kg	100	<10
Dalapon	mg/kg	1,000	<100
Dicamba	mg/kg	500	<50
Dinoseb	mg/kg	500	<50
2,4,5-T	mg/kg	100	<10
2,4,5-TP (Silvex)	mg/kg	100	<10
2,4-D	mg/kg	100	<10
2,4-DB	mg/kg	100	<10
Pesticides(2)			
Alachlor	mg/kg	100	<10
Aldrin	mg/kg	0.08	<0.008
α-BHC	mg/kg	50	<5
β-BHC	mg/kg	10	<1
y-BHC (Lindane, y-HCH)	mg/kg	0.003	<0.0003
δ-BHC	mg/kg	10	<1
Chlordane	mg/kg	5	<0.5
4,4-DDD (p,p')	mg/kg	8	<0.8
4,4-DDE (p,p')	mg/kg	6	<0.6
4,4-DDT (p,p')	mg/kg	6	<0.6
Dieldrin	mg/kg	0.08	<0.008
α-Endosulfan (I)	mg/kg	0.5	<0.05
β-Endosulfan (II)	mg/kg	0.5	<0.05
Endosulfan Sulfate	mg/kg		"See listed constituents"
Endrin	mg/kg	10	<1
Endrin Aldehyde	mg/kg	10	<1
Endrin ketone	mg/kg	10	<1
Heptachlor	mg/kg	0.3	<0.03
Heptachlor Epoxide	mg/kg	0.1	<0.01
Hexachlorobenzene	mg/kg	0.7	<0.07
Methoxychlor	mg/kg	200	<20
Toxaphene	mg/kg	10	<1

Summary of Site Specific Soil Acceptance Criteria
Stafford Street
Leicester, MA

Constituent	Units	MCP RCS-1	Site Specific Acceptance Criteria

MCP - Massachusetts Contingency Plan

RCS-1 - Reportable Concentration for soil meeting the criteria of S-1 as defined in 310 CMR 40.0361

mg/kg - milligrams/kilogram

EPH - MassDEP Extractable Petroleum Hydrocarbons

VPH - MassDEP Volatile Petroleum Hydrocarbons

Trace levels of certain constituents may be accepted on a case-by-case basis with appropriate assessment and justification

NE - Not Established

NA - Not Applicable

(1) - Must analyze if considered to be a chemical of concern at generating site

(2) - Testing for herbicides and pesticides must be performed if Source Site is known to have stored or used herbicides or pesticides

Table 2

Baseline Soil Sample Analytical Summary

Lot 35 D1.2 0

Stafford Street

Leicester, MA

Sample Date	Client ID	Arsenic Concentration	Lead Concentration	Units
9/16/2021	Stafford 1	29.3	7.39	mg/kg
9/16/2021	Stafford 2	25.7	5.84	mg/kg
9/16/2021	Stafford 3	48.9	7.55	mg/kg
9/16/2021	Stafford 4	32.0	7.04	mg/kg
9/16/2021	Stafford 5	22.9	5.30	mg/kg
9/16/2021	Stafford 6	22.7	5.05	mg/kg
9/16/2021	Stafford 7	20.7	5.48	mg/kg
9/16/2021	Stafford 8	20.2	5.15	mg/kg
9/16/2021	Stafford 9	23.1	9.58	mg/kg
9/16/2021	Stafford 10	31.0	10.90	mg/kg
11/10/2021	Staffordshire #11	38.8	7.04	mg/kg
11/10/2021	Staffordshire #12	42.4	8.78	mg/kg
11/10/2021	Staffordshire #13	52.5	12.50	mg/kg
11/10/2021	Staffordshire #14	35.3	7.00	mg/kg
11/10/2021	Staffordshire #15	33.7	8.46	mg/kg
11/10/2021	Staffordshire #16	27.3	5.84	mg/kg
11/10/2021	Staffordshire #17	59.6	17.50	mg/kg
11/10/2021	Staffordshire #18	43.9	12.00	mg/kg
11/10/2021	Staffordshire #19	28.5	8.18	mg/kg
11/10/2021	Staffordshire #20	45.2	9.86	mg/kg

ATTACHMENT C
LABORATORY ANALYTICAL REPORTS

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29984

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 1

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	29.3	0.74	mg/Kg	1	09/17/21	TH	SW6010D
Lead	7.39	0.37	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	87		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29985

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 2

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	25.7	0.83	mg/Kg	1	09/17/21	TH	SW6010D
Lead	5.84	0.42	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	86		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29986

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 3

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	48.9	0.75	mg/Kg	1	09/17/21	TH	SW6010D
Lead	7.55	0.37	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	86		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29987

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 4

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	32.0	0.69	mg/Kg	1	09/17/21	TH	SW6010D
Lead	7.04	0.34	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	89		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29988

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 5

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	22.9	0.69	mg/Kg	1	09/17/21	TH	SW6010D
Lead	5.30	0.35	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	85		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200. The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29989

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 6

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	22.7	0.75	mg/Kg	1	09/17/21	TH	SW6010D
Lead	5.05	0.37	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	88		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29990

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 7

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	20.7	0.76	mg/Kg	1	09/17/21	TH	SW6010D
Lead	5.48	0.38	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	90		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29991

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 8

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	20.2	0.77	mg/Kg	1	09/17/21	TH	SW6010D
Lead	5.15	0.38	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	88		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29992

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 9

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	23.1	0.68	mg/Kg	1	09/17/21	TH	SW6010D
Lead	9.58	0.34	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	87		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 17, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		09/16/21	8:00
Location Code:	CHARME	Received by:	CP	09/16/21	13:00
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ29984
Phoenix ID: CJ29993

Project ID: STAFFORD LEICESTER
Client ID: STAFFORD 10

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	31.0	0.75	mg/Kg	1	09/17/21	TH	SW6010D
Lead	10.9	0.38	mg/Kg	1	09/17/21	TH	SW6010D
Percent Solid	85		%		09/16/21	JS	SW846-%Solid
Total Metals Digest	Completed				09/16/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 17, 2021
Official Report Release To Follow

Friday, September 17, 2021

Criteria: None

State: MA

Sample Criteria Exceedances Report

GCJ29984 - CHARME

SampNo	Acode	Phoenix Analyte	Criteria	Result	RL	Criteria	RL Criteria	Analysis Units

*** No Data to Display ***

Phoenix Laboratories does not assume responsibility for the data contained in this exceedance report. It is provided as an additional tool to identify requested criteria exceedences. All efforts are made to ensure the accuracy of the data (obtained from appropriate agencies). A lack of exceedence information does not necessarily suggest conformance to the criteria. It is ultimately the site professional's responsibility to determine appropriate compliance.

Cooler: Yes ☒ No ☐
Coolant: IPK ☑ ICE ☒ No ☐

PHOENIX
Environmental Laboratories, Inc.

CHAIN OF CUSTODY RECORD

587 East Middle Turnpike, P.O. Box 370, Manchester, CT 06040
Email: info@phoenixlabs.com Fax (860) 645-0823
Client Services (860) 645-8726

Temp 2.3 °C Pg of

Data Delivery/Contact Options:
☐ Fax:
☒ Phone: 5088683455
☒ Email: charlie@charmematerials.com

Customer: Charme Materials
Address: 1660 Windy Pines Dr #6
Naples FL 34112
Charles Wilder

Project: Stafford - Leicester
Report to: CHW - Charme
Invoice to: Charme
QUOTE #

Project P.O:

This section MUST be completed with Bottle Quantities.

Client Sample - Information - Identification

Sampler's Signature Date: 9-16-21

Matrix Code:
DW=Drinking Water GW=Ground Water SW=Surface Water WW=Waste Water
RW=Raw Water SE=Sediment SL=Sludge S=Soil SD=Solid W=Wipe OIL=Oil
B=Bulk L=Liquid X = ____________(Other)

Analysis Request

PHOENIX USE ONLY SAMPLE #	Customer Sample Identification	Sample Matrix	Date Sampled	Time Sampled	Total ASenic	Total LEAD							DOCS	MS/MSD *	GL Amber 8 oz. w/H3PO4	Soil VOA Vials [ ] methanol [ ] H2O	GL Soil container ( )oz	GL Soil container ( )oz	40 ml VOA Vial [ ] As is [ ] HCl	GL Amber 1000ml [ ] As is [ ] H2SO4	PL As is [ ] 250ml [ ] 500ml [ ] 1000ml	PL H2SO4 [ ] 250ml [ ] 500ml	PL HNO3 250ml	PL NaOH 250ml	Bacteria Bottle w/thio	Bacteria Bottle as is
29984	STAFFORD 1	S	9-16	8am	X	X							X													
29985	" 2				X	X							X													
29986	" 3				X	X							X													
29987	" 4				X	X							X													
29988	" 5				X	X							X													
29989	" 6				X	X							X													
29990	" 7				X	X							X													
29991	" 8				X	X							X													
29992	" 9				X	X							X													
29993	" 10				X	X							X													

Relinquished by:	Accepted by:	Date:	Time: 1049
		9-16	8am
	8Z	9/16/21	13:00

Comments, Special Requirements or Regulations:
10 - Grab samples
Stafford St property Leicester MA

Turnaround Time:
☒ 1 Day*
☐ 2 Days*
☐ 3 Days*
☐ Standard
☐ Other
* SURCHARGE APPLIES

*MS/MSD are considered site samples and will be billed as such in accordance with the prices quoted.

RI
☐ (Residential)
☐ (Comm/Industrial) Direct Exposure
☐ GA Leachability
☐ GB Leachability
☐ GA-GW Objectives
☐ GB-GW Objectives

CT
☐ RCP Cert
☐ GW Protection
☐ SW Protection
☐ GA Mobility
☐ GB Mobility
☐ Residential DEC
☐ I/C DEC
☐ Other

MA
☐ MCP Certification
☐ GW-1 ☐ MWRA eSMART
☐ GW-2 ☐ S-1 10% CALC
☐ GW-3
☐ S-1 GW-1 ☐ S-1 GW-2 ☐ S-1 GW-3
☐ S-2 GW-1 ☐ S-2 GW-2 ☐ S-2 GW-3
☐ S-3 GW-1 ☐ S-3 GW-2 ☐ S-3 GW-3
☐ SW Protection

State where samples were collected: MA

Data Format
☐ Excel
☒ PDF
☐ GIS/Key
☐ EQuIS
☐ Other

Data Package
☐ Tier II Checklist
☐ Full Data Package*
☐ Phoenix Std Report
☐ Other

* SURCHARGE APPLIES

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	11:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75758

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #11

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	38.8	0.75	mg/Kg	1	11/12/21	TH	SW6010D
Lead	7.04	0.37	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	86		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	11:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75759

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #12

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	42.4	0.77	mg/Kg	1	11/12/21	TH	SW6010D
Lead	8.78	0.39	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	82		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	11:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75760

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #13

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	52.5	0.83	mg/Kg	1	11/12/21	TH	SW6010D
Lead	12.5	0.42	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	86		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	11:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75761

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #14

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	35.3	0.73	mg/Kg	1	11/12/21	TH	SW6010D
Lead	7.00	0.37	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	84		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	11:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75762

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #15

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	33.7	0.77	mg/Kg	1	11/12/21	TH	SW6010D
Lead	8.46	0.39	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	81		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	12:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75763

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #16

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	27.3	0.78	mg/Kg	1	11/12/21	TH	SW6010D
Lead	5.84	0.39	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	86		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	12:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75764

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #17

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	59.6	0.79	mg/Kg	1	11/12/21	TH	SW6010D
Lead	17.5	0.39	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	86		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	12:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75765

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #18

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	43.9	0.79	mg/Kg	1	11/12/21	TH	SW6010D
Lead	12.0	0.39	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	88		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	12:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75766

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #19

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	28.5	0.89	mg/Kg	1	11/12/21	TH	SW6010D
Lead	8.18	0.44	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	74		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 12, 2021

FOR: Attn: Mr. Charles Wilder
Charme Materials Solutions, LLC
PO Box 82
Sutton, MA 01590

Sample Information		Custody Information		Date	Time
Matrix:	SOIL	Collected by:		11/10/21	12:00
Location Code:	CHARME	Received by:	CP	11/11/21	13:08
Rush Request:	24 Hour	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GCJ75758
Phoenix ID: CJ75767

Project ID: STAFFORDSHIRE LEICESTER
Client ID: STAFFORDSHIRE #20

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Arsenic	45.2	0.88	mg/Kg	1	11/12/21	TH	SW6010D
Lead	9.86	0.44	mg/Kg	1	11/12/21	TH	SW6010D
Percent Solid	73		%		11/11/21	Q	SW846-%Solid
Total Metals Digest	Completed				11/11/21	M/AG	SW3050B

Massachusetts does not offer certification for Soil/Solid matrices.

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If you are the client above and have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext.200.
The contents of this report cannot be discussed with anyone other than the client listed above without their written consent.

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 12, 2021
Official Report Release To Follow

Friday, November 12, 2021

Criteria: None

State: MA

Sample Criteria Exceedances Report

GCJ75758 - CHARME

SampNo	Acode	Phoenix Analyte	Criteria	Result	RL	Criteria	RL Criteria	Analysis Units

*** No Data to Display ***

Phoenix Laboratories does not assume responsibility for the data contained in this exceedance report. It is provided as an additional tool to identify requested criteria exceedences. All efforts are made to ensure the accuracy of the data (obtained from appropriate agencies). A lack of exceedence information does not necessarily suggest conformance to the criteria. It is ultimately the site professional's responsibility to determine appropriate compliance.

Cooler: Yes ☑ No ☐
Coolant: IPK ☑ ICE ☐ No ☐

CHAIN OF CUSTODY RECORD

PHOENIX
Environmental Laboratories, Inc

587 East Middle Turnpike, P.O. Box 370, Manchester, CT 06040
Email: info@phoenixlabs.com Fax (860) 645-0823
Client Services (860) 645-8726

Temp 2.0 °C Pg of

Data Delivery/Contact Options:
☐ Fax:
☐ Phone:
☐ Email:

Customer: Charme McFalls
Address: 1660 Windy Pines Dr #4
Naples FL 34112

Project: Staffordshire Leicester
Report to: C+W
Invoice to: Charme
QUOTE # NA
Project P.O:

This section MUST be completed with Bottle Quantities.

Client Sample - Information - Identification
Sampler's Signature Date: 11-10-21

Matrix Code:
DW=Drinking Water GW=Ground Water SW=Surface Water WW=Waste Water
RW=Raw Water SE=Sediment SL=Sludge S=Soil SD=Solid W=Wipe OIL=Oil
B=Bulk L=Liquid X = ________(Other)

Analysis Request

PHOENIX USE ONLY SAMPLE #	Customer Sample Identification	Sample Matrix	Date Sampled	Time Sampled	Total Lead	Total Arsenic	MS/MSD *	GL Amber 8 oz. w/H3PO4	Soil VOA Vials [ ] methanol [ ] H2O	GL Soil container ( ) oz	GL Soil container ( ) oz	40 ml VOA Vial [ ] As is [ ] HCl	GL Amber 1000ml [ ] As is [ ] H2SO4	PL As is [ ] 250ml [ ] 500ml [ ] 1000ml	PL H2SO4 [ ] 250ml [ ] 500ml	PL HNO3 250ml	PL NaOH 250ml	Bacteria Bottle w/thio	Bacteria Bottle as is
75758	Staffordshire #11	S	11-10	11 AM	X	X													
75759	#12				X	X													
75760	#13				X	X													
75761	#14				X	X													
75762	#15				X	X													
75763	#16			12 pm	X	X													
75764	#17				X	X													
75765	#18				X	X													
75766	#19				X	X													
75767	#2				X	X													

Relinquished by:	Accepted by:	Date:	Time:
		11/11/21	1155
		11/11	1308

Comments, Special Requirements or Regulations:
RUSH

Turnaround Time:
☒ 1 Day*
☐ 2 Days*
☐ 3 Days*
☐ Standard
☐ Other
* SURCHARGE APPLIES

MS/MSD are considered site samples and will be billed as such in accordance with the prices quoted.

RI
☐ (Residential)
☐ (Comm/Industrial) Direct Exposure
☐ GA Leachability
☐ GB Leachability
☐ GA-GW Objectives
☐ GB-GW Objectives

CT
☐ RCP Cert
☐ GW Protection
☐ SW Protection
☐ GA Mobility
☐ GB Mobility
☐ Residential DEC
☐ I/C DEC
☐ Other

MA
☐ MCP Certification
☐ GW-1 ☐ MWRA eSMART
☐ GW-2 ☐ S-1 10% CALC
☐ GW-3
☐ S-1 GW-1 ☐ S-1 GW-2 ☐ S-1 GW-3
☐ S-2 GW-1 ☐ S-2 GW-2 ☐ S-2 GW-3
☐ S-3 GW-1 ☐ S-3 GW-2 ☐ S-3 GW-3
☐ SW Protection

State where samples were collected: MA

Data Format
☐ Excel
☒ PDF
☐ GIS/Key
☐ EQuIS
☐ Other

Data Package
☐ Tier II Checklist
☐ Full Data Package*
☐ Phoenix Std Report
☐ Other
* SURCHARGE APPLIES

ATTACHMENT D
ADDITIONAL INFORMATION

LIGHTHOUSE
ENVIRONMENTAL
MANAGEMENT LLC

THE GREEN BUILDING
184 Stone Street, Clinton, MA 01510

SOIL REUSE SUBMITTAL FORM

PROFILE NUMBER ______________
(LIGHTHOUSE USE)

A. SITE INFORMATION:

Name:	Contact:
Address:	Phone:
City:	State, Zip:
Release Tracking No. or Site ID No. (if applicable):	

B. GENERATOR INFORMATION:

Name:	Contact:
Address:	Phone:
City:	State, Zip:

C. CONSULTANT INFORMATION:

Company:	Contact:
Address:	Phone:
City:	State, Zip:

D. ESTIMATED SOIL QUANTITY:

Tons: or	Cubic Yards:

E. LABORATORY ANALYSIS

Check the following laboratory analysis performed on the material to be reused (check all that apply)

☐ VOCs, SVOCs, TPH, PCBs
☐ MCP14 Metals
☐ TCLP (if required by total levels)
☐ Conductivity
☐ Ignitability/Flash Point
☐ Pesticides
☐ pH
☐ Reactivity
☐ Herbicides
☐ Other laboratory analysis performed: ______________________________

☐ Field screening performed (describe below)
____

☐ Attach data summary tables for all soil from source and laboratory reports for only applicable samples

F. SITE HISTORY:

☐ Check if extra sheet attached

Current Use(s):

Past Use(s):

Check additional site history/uses below. Provide additional description as needed:

Tannery Yes ___ No ___
Textiles Yes ___ No ___
Foundry Yes ___ No ___
Dry Cleaning Yes ___ No ___
Coal Gasification Yes ___ No ___
Machine Shop Yes ___ No ___
Salvage/Junk Yard Yes ___ No ___
Petroleum Storage Yes ___ No ___
Plating/metal finishing Yes ___ No ___
Chemical Production Yes ___ No ___
Circuit Board Manufacturer Yes ___ No ___
Herbicide or Pesticide use, storage, or disposal Yes ___ No ___
Historic Urban Fill Soil present Yes ___ No ___
Boston Blue Clay present Yes ___ No ___
Soil with elevated natural background of Arsenic or other constituents Yes ___ No ___
Dumping Ground for dredge spoils, fill soil, ash waste, or other waste Yes ___ No ___
Source of soil is on an MCP Disposal Site RTN __________
Source of soil is adjacent/near to an MCP Disposal Site RTNs __________

G. PHYSICAL SOIL DESCRIPTION:

Physical Description (sand, gravel, silt, peat, fill, clay etc.):

Check if the following materials are present (check all that apply):

☐ Clay ☐ Coal ☐ Ash

☐ Construction Debris ☐ Vegetative Matter ☐ Other Material: ______________

H. SOIL SAMPLING METHODOLOGY:

Sampling Methods (check all that apply):

☐ Grab ☐ Composite (Acceptance criteria based on grab samples)

☐ Headspace Screened ☐ Visually Contaminated ☐ Olfactory Contaminated

☐ Other: ______________

I. SOIL CHARACTERIZATION METHODOLOGY:

Soil Characterization (check all that apply):

☐ Stockpile ☐ In-situ ☐ Other: ______________

No. of Samples Collected:	

"Hotspots" identified (material not suitable for reuse at SITE :

Describe how "hotspots" were segregated (if applicable):

J. CERTIFICATION

I, the generator, having used due diligence and determined that the soil described within this Soil Submittal Package and intended for reuse at Project meets the acceptance criteria, screening procedures, and due diligence described within the Fill Management Plan. There is no reason to suspect or believe soil intended for reuse at this SITE has been impacted by any releases of oil or hazardous materials or contains any other contaminants than those at levels described herein. I agree to promptly remove any soil delivered to the site that is determined by LIGHTHOUSE ENV MGMT to not meet acceptance criteria. Should LIGHTHOUSE ENV MGMT take action and remove such soil from the site and manage that material elsewhere, LIGHTHOUSE will seek payment from the Generator for all costs including damages.

Signature of Generator:	Date:
Generator - Printed Name:	

K. SITE DIAGRAM:

A site diagram is required indicating any major structures, roads, excavation areas, soil origin, sample locations, and stockpile locations. All sampling locations must be noted:

☐Check if Diagram is Attached

MassDEP
Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

DEVAL L. PATRICK
Governor

MAEVE VALLELY BARTLETT
Secretary

DAVID W. CASH
Commissioner

Similar Soils Provision Guidance

Guidance for Identifying When Soil Concentrations at a Receiving Location Are "Not Significantly Lower Than" Managed Soil Concentrations Pursuant to 310 CMR 40.0032(3)

September 4, 2014[1]
(Originally published October 2, 2013 and revised April 25, 2014[2])

WSC#-13-500

The information contained in this document is intended solely as guidance. This guidance does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. Parties using this guidance should be aware that there may be other acceptable alternatives for achieving and documenting compliance with the applicable regulatory requirements and performance standards of the Massachusetts Contingency Plan.

I. Purpose and Scope

The Massachusetts Contingency Plan ("MCP", 310 CMR 40.0000) establishes conditions and requirements for the management of soil excavated at a disposal site. This guidance addresses the specific requirements of 310 CMR 40.0032(3) and the criteria by which a Licensed Site Professional ("LSP") may determine that soil may be moved without prior notice to or approval from the Department. Soil managed pursuant to 310 CMR 40.0032(3) may be transported using a Bill of Lading ("BOL"), but a BOL is not required. Attachment 1 provides a flowchart depiction of the Similar Soil regulations and guidance.

This guidance is not applicable to the excavation and movement of soil from locations other than M.G.L. Chapter 21E disposal sites, nor to the management of soils considered Remediation Waste under the MCP.

---

[1] Updated to revise an inaccurate RCS-1 concentration for lead in Table 2 and an inaccurate RCS-2 concentration for selenium in Table 3.

[2] Updated to reflect the 2014 revisions to the Massachusetts Contingency Plan, 310 CMR 40.0000

II. Relationship to Other Local, State or Federal Requirements

This guidance is intended to clarify and more fully describe regulatory requirements contained within the MCP. Nothing in this guidance eliminates, supersedes or otherwise modifies any local, state or federal requirements that apply to the management of soil, including any local, state or federal permits or approvals necessary before placing the soil at the receiving location, including, *but not limited to,* those related to placement of fill, noise, traffic, dust control, wetlands, groundwater or drinking water source protection.

III. Requirements of 310 CMR 40.0032(3)

The requirements specified in 310 CMR 40.0032(3) are:

> (3) Soils containing oil or waste oil at concentrations less than an otherwise applicable Reportable Concentration and that are not otherwise a hazardous waste, and soils that contain one or more hazardous materials at concentrations less than an otherwise applicable Reportable Concentration and that are not a hazardous waste, may be transported from a disposal site without notice to or approval from the Department under the provisions of this Contingency Plan, provided that such soils:
>
> (a) are not disposed or reused at locations where the concentrations of oil or hazardous materials in the soil would be in excess of a release notification threshold applicable at the receiving site, as delineated in 310 CMR 40.0300 and 40.1600; and
>
> (b) are not disposed or reused at locations where existing concentrations of oil and/or hazardous material at the receiving site are significantly lower than the levels of those oil and/or hazardous materials present in the soil being disposed or reused.

There are therefore four requirements that must be met before the managed soil can be moved to and re-used (or disposed) at a new location without notice to or approval from MassDEP. Each requirement (A. through D.) is addressed below.

A. The Managed Soil Must Not Be a Hazardous Waste

310 CMR 40.0032(3) applies to soils containing oil or waste oil that are not otherwise a hazardous waste, and to soils containing hazardous materials that are not a hazardous waste. The MCP definition of hazardous waste (310 CMR 40.0006) refers to the definitions promulgated in the Massachusetts Hazardous Waste Regulations, 310 CMR 30.000.

Under the federal Resource Conservation and Recovery Act of 1976 (“RCRA”, 42 U.S.C. §§6901 *et. seq.*), the Massachusetts Hazardous Waste Management Act (M.G.L. c.21C), and the Massachusetts Hazardous Waste Regulations (310 CMR 30.000), soil is considered to contain a hazardous waste (hazardous waste soil) if, when generated, it meets either or both of the following two conditions:

- the soil exhibits one or more of the characteristics of a hazardous waste pursuant to 310 CMR 30.120 [such as exhibiting a characteristic of toxicity under 310 CMR 30.125 and 30.155 (Toxicity Characteristic Leaching Procedure, or TCLP)]; or
- the soil contains hazardous constituents from a listed hazardous waste identified in 310 CMR 30.130 or Title 40, Chapter I, Part 261 (Identification and Listing of Hazardous Waste) of the Code of Federal Regulations.

MassDEP has published a Technical Update entitled: *Considerations for Managing Contaminated Soil: RCRA Land Disposal Restrictions and Contained-In Determinations* (August 2010, http://www.mass.gov/eea/docs/dep/cleanup/laws/contain.pdf) that focuses on the determination of whether contaminated soil must be managed as a hazardous waste subject to RCRA requirements, and the presumptive approval process an LSP/PRP can use to document such a determination.

B. The Managed Soil Must Be Less Than Reportable Concentrations (RCs).

This requirement is intended to ensure that the soil being excavated and relocated from a disposal site is not "Contaminated Soil" and therefore neither "Contaminated Media" nor "Remediation Waste" as those terms are defined in 310 CMR 40.0006[3].

310 CMR 40.0361 sets forth two reporting categories for soil (RCS-1 and RCS-2). Reporting Category RCS-1 applies to locations with the highest potential for exposure, such as residences, playgrounds and schools, and to locations within the boundaries of a groundwater resource area. Reporting Category RCS-2 applies to all other locations.

Note that the "applicable Reportable Concentrations" referred to in 310 CMR 40.0032(3) may be the RCS-1 or RCS-2 criteria, depending upon which category would apply to the soils being excavated *at the original disposal site location*, not the RCs applicable to the soils at the receiving location (see Section III.C. below).

> **EXAMPLE:** If soil is being excavated from a disposal site at an RCS-2 location and the soil contaminant concentrations are found to be less than the RCS-2 criteria, then the soil is not "Contaminated Soil" since the soil is less than the release notification threshold established for RCS-2 soil by 310 CMR 40.0300 and 40.1600. The RCS-2 soil in this example is not "Contaminated Soil" even if one or more constituent concentration is greater than an RCS-1 value.

Also, the language at 310 CMR 40.0032(3) specifies the *applicable* RCs. If a notification exemption (listed at 310 CMR 40.0317) applies to the OHM in soil at its original location, then the corresponding Reportable Concentration is not *applicable*. Thus 310 CMR 40.0032(3) should be read to apply to soils containing concentrations of oil or hazardous material ("OHM") less than the applicable RCs *or* covered by a notification exemption. This interpretation of the requirement is consistent with the definition of Contaminated Soil, which uses the term "notification threshold" rather than "Reportable Concentration."

---

[3] Contaminated Soil - means soil containing oil and/or hazardous material at concentrations equal to or greater than a release notification threshold established by 310 CMR 40.0300 and 40.1600.

Contaminated Media - means Contaminated Groundwater, Contaminated Sediment, Contaminated Soil, and/or Contaminated Surface Water.

Remediation Waste - means any Uncontainerized Waste, Contaminated Media, and/or Contaminated Debris that is managed pursuant to 310 CMR 40.0030. The term "Remediation Waste" does not include Containerized Waste.

C. The Managed Soil Must Not Create a Notifiable Condition at the Receiving Location.

This requirement is intended to prevent the creation of new reportable releases that must be subsequently assessed and remediated.

If the contaminant concentrations in the soil being relocated are less than the RCS-1 criteria, then placement of the soil in any RCS-1 location would not create a new notifiable condition. There are, however, conditions that could result in a notifiable condition.

> First, if the soil is excavated from an RCS-2 location (as described in the example in Section III.B. above) with contaminant concentrations *between* the RCS-1 and RCS-2 criteria, then the placement of that soil at an RCS-1 receiving location would create a notifiable condition since one or more concentrations of OHM would then exceed the RCS-1 criteria in the RCS-1 receiving location.
>
> Second, a notification exemption that applies to the original location of the soil may not apply to the receiving location. (For example, the lead paint exemption at 310 CMR 40.0317(8) is specific to "the point of application.") In cases where a notification exemption applies only to the original location, the managed soil must be evaluated solely based on whether its OHM concentrations exceed the applicable RCs at the receiving location.

D. The Managed Soil Must Not Be Significantly More Contaminated Than the Soil at the Receiving Location.

This requirement has been referred to as the "anti-degradation provision" although it is more accurately described as the "Similar Soils Provision." 310 CMR 40.00032(3)(b) requires that the concentrations of OHM at the receiving location not be "significantly lower" than the relocated soil OHM concentrations. One could also say that the provision requires that "there is no significant difference between the relocated soil and the soil at the receiving location," or that "the soils being brought to the receiving location are similar to what is already there." This requirement embodies several considerations.

> First, as a general principle, M.G.L. c.21E is intended to clean up contaminated properties and leave them better than they started -- even to clean sites to background conditions, if feasible. It would be inconsistent with this principle to then raise the ambient levels of contamination in the environment as a consequence of a response action conducted under the MCP.
>
> Second, despite the three other requirements (A. through C. above) of 310 CMR 40.0032(3), decisions about the movement of the managed soil will be based upon sampling of soil that is likely to have significant heterogeneity. The Similar Soils Provision is an additional measure to minimize the adverse effects of soil characterization that may not be representative of such heterogeneity.

> Third, none of the criteria of 310 CMR 40.0032(3) address the question of whether the soil poses a *risk* in its original or receiving location, although the hazardous waste- and notification-related requirements seem to *imply* risk-based decision making. Put simply, soil that is not a hazardous waste and does not require notification may still pose incremental risk at the receiving location. The Similar Soils Provision is intended to ensure that the managed soil does not increase risk of harm to health, safety, public welfare or the environment at the receiving location, since it will be similar to what is already there.

The "not… significantly lower" language of 310 CMR 40.0032(3)(b) can be interpreted to mean either a quantitative "not statistically different" analysis, or a semi-quantitative, albeit somewhat subjective, approach. MassDEP does not believe that a statistics-driven quantitative approach is necessary when comparing managed soil to known or assumed background conditions, given (a) the relatively low concentrations at issue and (b) the cost of such an analysis, driven by the quantity of sampling needed to show a statistical difference.

The regulations imply that the LSP must have knowledge about the concentrations of OHM in the soil at the receiving location in order to apply the Similar Soils Provision. The regulations also imply that the new soil may contain concentrations of OHM that are *somewhat* higher than those levels at the receiving location – just not "significantly" higher.

MassDEP recognizes that there may be several approaches to address this "knowledge" issue when implementing the Similar Soils Provision of the MCP.

- **Assume the soils at the receiving location are natural background**.
  Sampling of the soil at the receiving location is not necessary if it is assumed that the concentrations of OHM there are consistent with natural background conditions. MassDEP acknowledges that there is a range of background levels, and that the concentrations at any given location may be lower than the statewide levels published by the Department[4], but the costs associated with determining site-specific background are not justified by likely differences. Further, the published "natural background" levels are similarly used in several areas of the MCP as an acceptable endpoint, including site delineation and the development of the MCP cleanup standards.

  Of course, routine due diligence about the receiving location may still reveal factors that would make the location inappropriate to receive the proposed fill material. Nothing in this guidance relieves any party of the obligation to conduct such due diligence and appropriately consider and act on information thereby obtained.

---

[4] *See* Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil (May, 2002) http://www.mass.gov/eea/docs/dep/cleanup/laws/backtu.pdf

- **Sample the soils at the receiving location**.
  The sampling plan should include a sufficient number of samples taken at locations selected to provide an understanding of the concentrations of OHM present and the distribution of OHM throughout the receiving location. In order to provide data appropriate for the Similar Soils comparison, the soil at the receiving location should be analyzed for constituents that are likely to be present there (e.g., naturally occurring metals) as well as any OHM known or likely to be present in the soil brought from the disposal site. If a receiving location has been adequately and comprehensively characterized, that data may then be used for comparison to the OHM concentrations in any subsequent soil deliveries - additional sampling is not required.

- **Provide Technical Justification for an Alternative Approach**
  There may be situations for which a different combination of analytical and non-analytical information available for both the source and receiving locations is sufficient to conclude that the nature and concentrations of OHM in the soils are not significantly different. Guidance on recognizing such conditions and the level of documentation that would be necessary to support such a technical justification is beyond the scope of this guidance.

Once the concentrations of OHM in the soils are known (or assumed consistent with this guidance), the LSP must compare the concentrations of the source and receiving locations and determine whether the concentrations at the receiving location are “significantly lower” than those in the soil proposed to be relocated from the disposal site. This comparison may be conducted in several ways, including analyses with appropriate statistical power and confidence. MassDEP has also developed a *rule-of-thumb* comparison to simplify this determination, as described in Section IV.

IV. Determining whether soils at the receiving location are “significantly lower” using a simplified approach

The simplified comparison shall be made using the *maximum* values of the OHM concentrations in both the soil at the receiving location and the soil proposed to be disposed of or reused.

Use of the maximum values is appropriate for several reasons. First, the provisions of 310 CMR 40.0032(3) include comparisons to Reportable Concentrations, and notification is triggered by any single value (i.e., maximum value) exceeding the RC. Second, soil is by its nature heterogeneous, and the use of maximum values is a means of minimizing sampling costs while addressing the expected variability of results. Third, if natural background levels are assumed at the receiving location, the MassDEP published background concentrations are upper percentile levels that are only appropriately compared to similar (e.g., maximum) values of the soil data set.

Note also that when using the maximum reported concentrations for comparison purposes, the typical or average concentration will be lower. This is important to recognize if/when the question of the risk posed by the soil is raised. For example, the RCS-1 and the Method 1 S-1 standard for arsenic are both 20 mg/kg. The Reportable Concentration is applied as a not-to-be-exceeded value, triggering the need to report the release and investigate further. However the S-1 standard is applied as an average value, considering exposure over time. At a location where the highest arsenic value found is less than 20 mg/kg, the average concentration would be well below the Method 1 S-1 standard.

The maximum concentration in the soil at the receiving location may be less than that in the proposed disposed/reused soil by some amount and not be considered “significantly lower.” The question is how much lower is “significantly lower”? In this guidance, MassDEP establishes a multiplying factor to be applied to the concentration in the soil at the receiving location. The multiplying factor varies depending upon the concentration in the soil at the receiving location, as shown in Table 1.

Table 1. Receiving Soil Concentration Multiplying Factors

If the concentration in soil at the receiving location for a given OHM is:	Then use a multiplying factor of:
< 10 mg/kg	10
10 mg/kg ≤ *x* <100 mg/kg	7.5
100 mg/kg ≤ *x* <1,000 mg/kg	5
≥ 1,000 mg/kg	2.5

EXAMPLE: The soil at a receiving location that is considered RCS-1 is appropriately sampled and the maximum concentration of silver is found to be 6 mg/kg. Using Table 1, the concentration of silver at the receiving location would not be considered “significantly lower” than *10 x 6 mg/kg = 60 mg/kg*. Since 60 mg/kg is less than the silver RCS-1 value of 100 mg/kg, soil containing a maximum concentration that is less than 60 mg/kg silver could be reused at this location.

EXAMPLE: The soil at a receiving location that is considered RCS-1 is assumed to be consistent with natural background. The MassDEP published natural background level for arsenic is 20 mg/kg. Using Table 1, the concentration of arsenic at the receiving location would not be considered “significantly lower” than *7.5 x 20 mg/kg = 150 mg/kg*. However, since 150 mg/kg is greater than the arsenic RCS-1 value of 20 mg/kg, only soil containing a maximum concentration that is less than 20 mg/kg arsenic could be reused at this location. [The managed soil must not create a notifiable condition at the receiving location, see Section III.C. above.]

> **EXAMPLE:** The soil at a receiving location that is considered RCS-2 is assumed to be consistent with natural background. The MassDEP published natural background level for benzo[a]anthracene is 2 mg/kg. Using Table 1, the concentration of benzo[a]anthracene at the receiving location would not be considered "significantly lower" than *10 x 2 mg/kg = 20 mg/kg*. Since 20 mg/kg is less than the benzo[a]anthracene RCS-2 value of 40 mg/kg, soil containing a maximum concentration that is less than 20 mg/kg benzo[a]anthracene could be reused at this location. [Note that due to the lower reportable concentration, RCS-1 receiving locations could only accept soil containing less than 7 mg/kg benzo[a]anthracene.]

The multiplying factors in Table 1 and the MassDEP published natural background levels can be used to establish concentrations of OHM in soil that would be acceptable for reuse at an RCS-1 receiving location, consistent with the requirements of 310 CMR 40.0032(3). Table 2 lists such concentrations. Note that soil that meets the criteria in Table 2 could be re-used at *any* location (RCS-1 or RCS-2). Similarly, Table 3 lists concentrations of OHM in soil that would be acceptable for reuse at an RCS-2 receiving location (but *not* RCS-1 locations).

If a chemical is not listed on these tables, then MassDEP has not established a natural background concentration[5]. This guidance is limited to the use of only MassDEP-published statewide background concentrations. Therefore an alternative approach, such as sampling the receiving location and comparing maximum reported concentrations, would be appropriate to meet the requirements of 310 CMR 40.0032(3).

---

[5] For example, MassDEP has not established natural background levels for PCBs, volatile organic compounds (VOCs) or petroleum-related constituents.

Table 2.
Limits to the Concentration of OHM In Soil for Re-Use Assuming Natural Background Conditions at an RCS-1 Receiving Location

OIL OR HAZARDOUS MATERIAL	Concentration In "Natural" Soil mg/kg	Rule-of-Thumb Multiplier	Multiplied Value mg/kg	RCS-1 mg/kg	Limiting[1] Soil Concentration mg/kg
ACENAPHTHENE	0.5	10	5	4	< 4
ACENAPHTHYLENE	0.5	10	5	1	< 1
ALUMINUM	10,000	2.5	25000		< 25000
ANTHRACENE	1	10	10	1000	< 10
ANTIMONY	1	10	10	20	< 10
ARSENIC	20	7.5	150	20	< 20
BARIUM	50	7.5	375	1000	< 375
BENZO(a)ANTHRACENE	2	10	20	7	< 7
BENZO(a)PYRENE	2	10	20	2	< 2
BENZO(b)FLUORANTHENE	2	10	20	7	< 7
BENZO(g,h,i)PERYLENE	1	10	10	1000	< 10
BENZO(k)FLUORANTHENE	1	10	10	70	< 10
BERYLLIUM	0.4	10	4	90	< 4
CADMIUM	2	10	20	70	< 20
CHROMIUM (TOTAL)	30	7.5	225	100	< 100
CHROMIUM(III)	30	7.5	225	1000	< 225
CHROMIUM(VI)	30	7.5	225	100	< 100
CHRYSENE	2	10	20	70	< 20
COBALT	4	10	40		< 40
COPPER	40	7.5	300		< 300
DIBENZO(a,h)ANTHRACENE	0.5	10	5	0.7	< 0.7
FLUORANTHENE	4	10	40	1000	< 40
FLUORENE	1	10	10	1000	< 10
INDENO(1,2,3-cd)PYRENE	1	10	10	7	< 7
IRON	20,000	2.5	50000		< 50000
LEAD	100	5	500	200	< 200
MAGNESIUM	5,000	2.5	12500		< 12500
MANGANESE	300	5	1500		< 1500
MERCURY	0.3	10	3	20	< 3
METHYLNAPHTHALENE, 2-	0.5	10	5	0.7	< 0.7
NAPHTHALENE	0.5	10	5	4	< 4
NICKEL	20	7.5	150	600	< 150
PHENANTHRENE	3	10	30	10	< 10
PYRENE	4	10	40	1000	< 40
SELENIUM	0.5	10	5	400	< 5
SILVER	0.6	10	6	100	< 6
THALLIUM	0.6	10	6	8	< 6
VANADIUM	30	7.5	225	400	< 225
ZINC	100	5	500	1000	< 500

[1] Concentration of OHM in soil must be LESS THAN (not equal or greater than) this value.

Table 3.
Limits to the Concentration of OHM In Soil for Re-Use Assuming Natural Background Conditions at an RCS-2 Receiving Location

OIL OR HAZARDOUS MATERIAL	Concentration In "Natural" Soil mg/kg	Rule-of-Thumb Multiplier	Multiplied Value mg/kg	RCS-2 mg/kg	Limiting[1] Soil Concentration mg/kg
ACENAPHTHENE	0.5	10	5	3000	< 5
ACENAPHTHYLENE	0.5	10	5	10	< 5
ALUMINUM	10,000	2.5	25000		< 25000
ANTHRACENE	1	10	10	3000	< 10
ANTIMONY	1	10	10	30	< 10
ARSENIC	20	7.5	150	20	< 20
BARIUM	50	7.5	375	3000	< 375
BENZO(a)ANTHRACENE	2	10	20	40	< 20
BENZO(a)PYRENE	2	10	20	7	< 7
BENZO(b)FLUORANTHENE	2	10	20	40	< 20
BENZO(g,h,i)PERYLENE	1	10	10	3000	< 10
BENZO(k)FLUORANTHENE	1	10	10	400	< 10
BERYLLIUM	0.4	10	4	200	< 4
CADMIUM	2	10	20	100	< 20
CHROMIUM (TOTAL)	30	7.5	225	200	< 200
CHROMIUM(III)	30	7.5	225	3000	< 225
CHROMIUM(VI)	30	7.5	225	200	< 200
CHRYSENE	2	10	20	400	< 20
COBALT	4	10	40		< 40
COPPER	40	7.5	300		< 300
DIBENZO(a,h)ANTHRACENE	0.5	10	5	4	< 4
FLUORANTHENE	4	10	40	3000	< 40
FLUORENE	1	10	10	3000	< 10
INDENO(1,2,3-cd)PYRENE	1	10	10	40	< 10
IRON	20,000	2.5	50000		< 50000
LEAD	100	5	500	600	< 500
MAGNESIUM	5,000	2.5	12500		< 12500
MANGANESE	300	5	1500		< 1500
MERCURY	0.3	10	3	30	< 3
METHYLNAPHTHALENE, 2-	0.5	10	5	80	< 5
NAPHTHALENE	0.5	10	5	20	< 5
NICKEL	20	7.5	150	1000	< 150
PHENANTHRENE	3	10	30	1000	< 30
PYRENE	4	10	40	3000	< 40
SELENIUM	0.5	10	5	700	< 5
SILVER	0.6	10	6	200	< 6
THALLIUM	0.6	10	6	60	< 6
VANADIUM	30	7.5	225	700	< 225
ZINC	100	5	500	3000	< 500

[1] Concentration of OHM in soil must be LESS THAN (not equal or greater than) this value.

V. Sampling Considerations

The soil proposed for disposal/re-use should be sampled at sufficient and adequately distributed locations so that the concentrations of the contaminants of concern in the soil are adequately characterized. This includes sampling for the purpose of MCP site assessment and sampling to characterize the soil in any given stockpile/shipment leaving the site. The factors listed below should be considered when developing and implementing such a sampling plan. Evaluation of release, source, and site specific conditions assist in developing the basis for the selection of field screening techniques, sampling methodologies, sampling frequencies, and the contaminants of concern (e.g., analytical parameters) used to characterize the soil. These include, but are not necessarily limited to the following:

- the type(s) and likely constituents known or suspected to be in the soil;
- current and former site uses, past incidents involving the spill or release of OHM, and past and present management practices of OHM at the site;
- the potential for the soil to contain listed hazardous waste or to be a characteristic hazardous waste;
- the presence or likelihood of any other OHM (e.g., chlorinated solvents, metals, polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs) , halogenated volatile organic compounds (VOCs));
- visual/olfactory observations, field screening, analytical data, and/or in-situ pre-characterization data;
- soil matrix type - naturally occurring soil or fill/soil mixtures (e.g., homogeneous or heterogeneous soil conditions);
- the identification and segregation of discrete "hot spots";
- the concentration variability in the soil;
- the volume of soil;
- the current and likely future exposure potential at the receiving location, including the potential for sensitive receptors, such as young children, to contact the soil (for example, more extensive sampling of the stockpiles would be warranted for soil slated to be moved to a residential setting than for soil being moved to a secure, low-exposure potential regulated receiving facility); and
- any sampling requirements stipulated by the receiving location.

The assessment of the soil, including the nature and concentrations of OHM therein, is a component of the MCP site assessment and therefore must meet all applicable performance standards, including those for environmental sample collection, analysis and data usability[6]. The assessment should address the precision, accuracy, completeness, representativeness, and comparability of the sampling and analytical results used to determine whether the soil

---

[6] Additional guidance on data usability is available in Policy #WSC-07-350, MCP Representativeness Evaluations and Data Usability Assessments. http://www.mass.gov/eea/docs/dep/cleanup/laws/07-350.pdf

stockpiles meet the Similar Soils Provision requirements. The representativeness of any site assessment sampling data if used to characterize contaminant concentrations in soil to be moved and reused offsite should be carefully evaluated. Additional guidance on soil sampling considerations is available from U.S. EPA and other state environmental agencies.[7]

VI. Segregation and Management of Soils of Different Known Quality

Soil containing concentrations of OHM equal to or greater than the values listed in Table 3 cannot be managed using the streamlined approach described in this guidance. Such soil must be managed in a manner consistent with its regulatory classification, which may include management as a hazardous waste, as a remediation waste, or under a case-specific Similar Soils determination.

Segregation of soil of different quality should occur based upon *in-situ* pre-characterization sampling results. Stockpiles of soil are mixtures that would require more extensive sampling to document the effectiveness of any attempted post-excavation segregation.

The known presence of soil that exceeds the Table 3 concentrations and the subsequent segregation of soil is one factor that would indicate the need for more frequent sampling (at least in that area of soil excavation) as described in Section V.

---

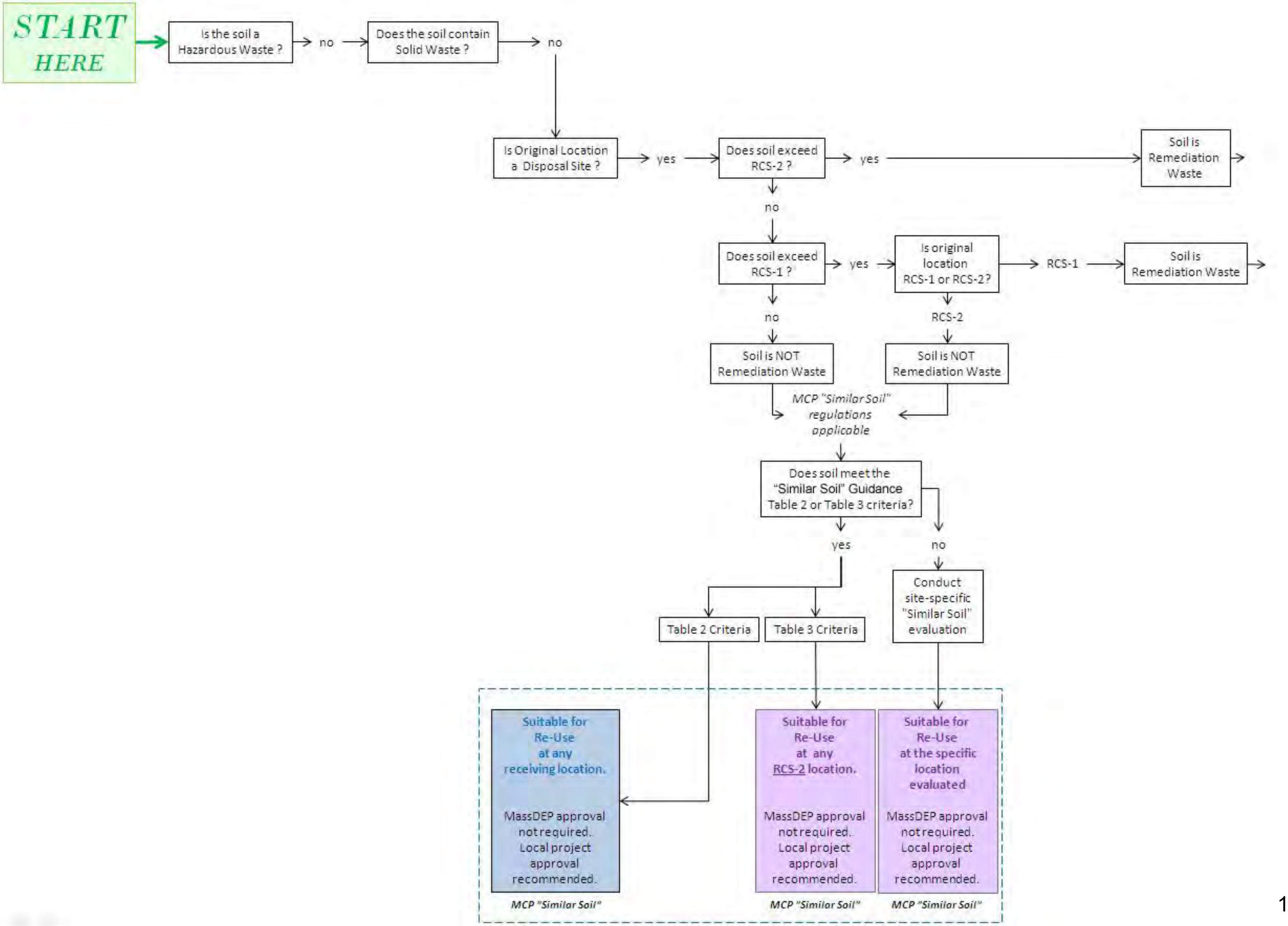
[7] Note that the guidance below are not specific to MGL Chapter 21E disposal sites and may not reflect MCP-specific considerations to determine the suitability of soils for offsite transport and use, such as for residential and other S-1 locations.

NJDEP. 2011. Alternative and Clean Fill Guidance for SRP Sites.
New Jersey Department of Environmental Protection Site Remediation Program
http://www.state.nj.us/dep/srp/guidance/srra/fill_protocol.pdf

USEPA. 1992. Supplemental Guidance to RAGS: Calculating the Concentration Term.
Office of Solid Waste and Emergency Response (OSWER), Washington, DC
http://www.epa.gov/oswer/riskassessment/pdf/1992_0622_concentrationterm.pdf

USEPA. 1995. Superfund Program Representative Sampling Guidance Volume 1: Soil.
OSWER. Washington, DC.
(Note that guidance for determining the number of samples for statistical analysis is addressed in Section 5.4.1).
http://www.epa.gov/tio/download/char/sf_rep_samp_guid_soil.pdf

Attachment 1 – Similar Soil Flowchart



USGS
science for a changing world

Prepared in cooperation with the
Massachusetts Department of Environmental Protection
and the Massachusetts Department of Public Health

Arsenic and Uranium in Water from Private Wells Completed in Bedrock of East-Central Massachusetts—Concentrations, Correlations with Bedrock Units, and Estimated Probability Maps

Scientific Investigations Report 2011–5013

U.S. Department of the Interior
U.S. Geological Survey

Cover photos:

A quartz-diorite bedrock formation at the road cut northeast of the I-495, I-290 intersection, in Marlborough, Massachusetts. Photos by Marcus Waldron.

Arsenic and Uranium in Water from Private Wells Completed in Bedrock of East-Central Massachusetts—Concentrations, Correlations with Bedrock Units, and Estimated Probability Maps

By John A. Colman

Prepared in cooperation with the
Massachusetts Department of Environmental Protection and the
Massachusetts Department of Public Health

Scientific Investigations Report 2011–5013

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

Suggested citation:

Colman, J.A., 2011, Arsenic and uranium in water from private wells completed in bedrock of east-central Massachusetts—Concentrations, correlations with bedrock units, and estimated probability maps: U.S. Geological Survey Scientific Investigations Report 2011–5013, 113 p.

Contents

Figures

Tables

Conversion Factors and Datums

Multiply	By	To obtain
	Area	
square kilometer (km^2)	0.6214	square mile (mi^2)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = (1.8 × °C) + 32

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

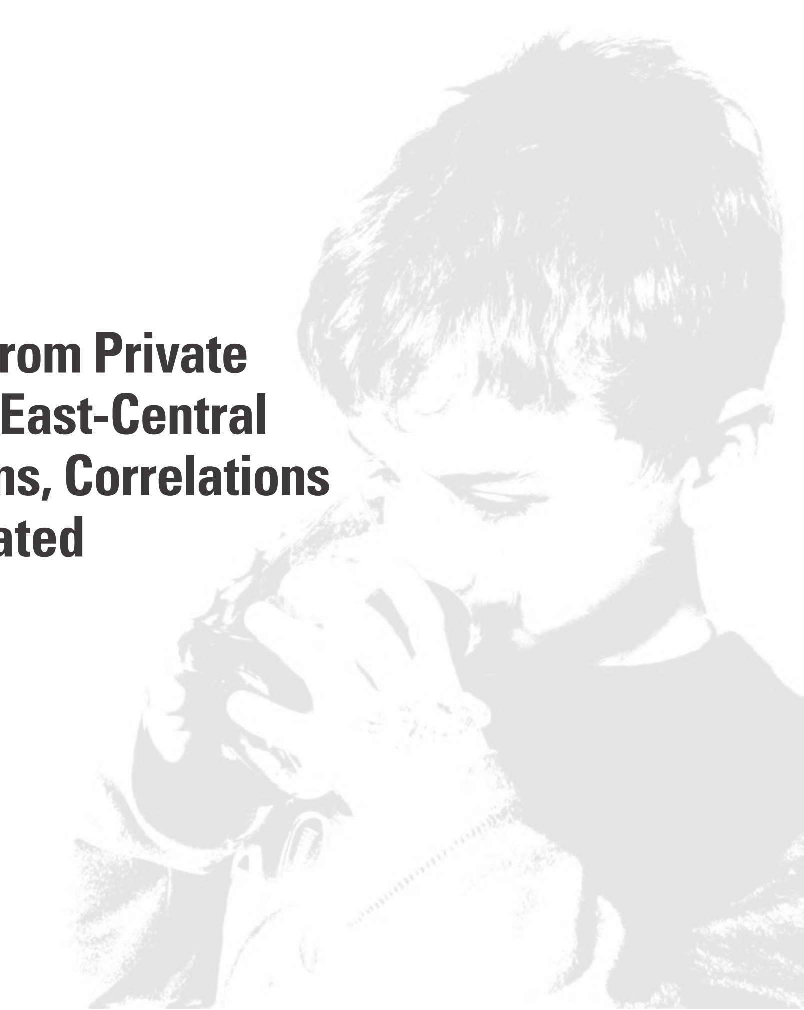
Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Acronyms and Additional Abbreviations

ANOVA	analysis of variance
GIS	Geographic Information System
MDEP	Massachusetts Department of Environmental Protection
MDPH	Massachusetts Department of Public Health
MCL	maximum contaminant level
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
mL	milliliter
NWQL	National Water Quality Laboratory
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Acknowledgments

This investigation would not have been possible without the participation of the many well users who sent in water samples for analysis. Discussion and project planning with the late Elaine Krueger was instrumental for development of the project. Support from the Massachusetts Department of Environmental Protection and the Massachusetts Department of Public Health is greatly appreciated.



Arsenic and Uranium in Water from Private Wells Completed in Bedrock of East-Central Massachusetts—Concentrations, Correlations with Bedrock Units, and Estimated Probability Maps

By John A. Colman

Abstract

Two U.S. Environmental Protection Agency drinking-water standards for public supplies involving groundwater contaminants that may derive from bedrock sources were promulgated between 2003 and 2006. A new arsenic drinking-water standard, a maximum contaminant level (MCL) of 10 micrograms per liter, became effective in January 2006. The non-radon radionuclides final standard took effect in December 2003, with an MCL for uranium of 30 micrograms per liter. This investigation, conducted in cooperation with the Massachusetts Department of Environmental Protection and the Massachusetts Department of Public Health, assessed the concentration ranges of arsenic and uranium in bedrock wells with reference to the new concentration standards, and associations of arsenic and uranium with bedrock units of the wells of east-central Massachusetts. The investigation focused on east-central Massachusetts, because State public bedrock-well databases indicate that arsenic concentrations in bedrock well water are elevated in that area. The project exploited the wide areal coverage of private wells to give the first detailed look at concentration distributions of arsenic and uranium through the high-arsenic zone of Massachusetts. The results establish statistical probabilities for elevated concentrations by bedrock unit at the scale of the State geologic map (1:250,000), which can guide future well-water testing, treatment, and supply development.

Well sampling was from 478 randomly selected wells by private-well users who were sent sampling-kit bottles with instructions and a water-use questionnaire. Results indicated that 13 percent of the randomly selected wells contained water with concentrations greater than the drinking-water standard established for public wells for arsenic, and 3.5 percent were greater than the standard for uranium. Arsenic and uranium did not in general co-occur in water of a given well. Of the wells with concentrations exceeding the standards, the questionnaire results indicated that 66 percent were being used for drinking water without treatment for arsenic, and 93 percent were being used without treatment for uranium.

Statistical analysis of the results indicated that distributions of arsenic and uranium concentrations grouped by bedrock unit were log normal. Statistically significant differences were found among distributions by bedrock unit for both arsenic and uranium. However, a zone of elevated concentrations of arsenic was found in groundwater west of the Clinton-Newbury fault (a boundary between two geologic terranes), where correlation between arsenic concentrations and the bedrock units was not significant.

Increased sampling in the investigation was directed in the regions of three 1:24,000 (7.5-minute) quadrangles where recent detailed geologic mapping had been conducted. Improved correlations of arsenic and uranium with bedrock unit were measured for two of the three quadrangles compared to the correlations made for the statewide map.

Cumulative distribution frequencies of concentrations grouped by rock unit or area (zone of elevated arsenic concentration) were used to assess the probability of wells having concentrations exceeding the drinking-water standards. The probabilities were mapped and applied to the estimated number of private wells in the study area to determine the likely number of wells in the study area with concentrations exceeding the standards. For arsenic and uranium, respectively, about 5,700 and 3,300 wells were estimated to contain concentrations exceeding the standards. Estimates for arsenic may approach the total number for the State, because the study area covered the principal known area of elevated arsenic concentrations.

Introduction

Two U.S. Environmental Protection Agency (USEPA) drinking-water standards involving groundwater contaminants that may derive from bedrock sources were promulgated between 2003 and 2006. A new maximum contaminant level (MCL) standard of 10 micrograms per liter (μg/L) for arsenic in drinking water became effective in February 2002, with compliance required by January 2006. The non-radon radionuclides final rule took effect in December 2003, with an MCL for uranium of 30 μg/L. The standards apply to public water supplies. In Massachusetts, the Massachusetts Department of Environmental Protection (MDEP) recommends that the standards also be used as guidelines for private supplies (Massachusetts Department of Environmental Protection, 2008).

Private water supply in Massachusetts, exclusive of the sand and gravel aquifers of the southeastern part of the State, is obtained primarily from wells drilled in bedrock (Hansen and Simcox, 1994). Bedrock water sources also are used for small commercial water supplies and, in some locations, for moderate to large municipal and industrial supplies (Hansen and Simcox, 1994; Lyford, and others 2003). Tens of thousands of private and public bedrock wells are used in the State —91,000 private bedrock wells were estimated for the bedrock geologic units investigated in this study.

Arsenic has long been known to be present in water from bedrock wells in east-central Massachusetts (Zuena and Keane, 1985; Ayotte and others, 2003; 2006), and the State straddles an arsenic belt that extends from Connecticut to New Brunswick, Canada. Elevated uranium concentrations in water from bedrock wells have been associated with igneous rock throughout New England, but also are present in water from other crystalline rock aquifers in the region (Ayotte and others, 2007). This investigation, conducted by the U.S. Geological Survey (USGS) in cooperation with the Massachusetts Department of Environmental Protection (MDEP) and the Massachusetts Department of Public Health (MDPH), was designed to assess the concentration ranges and associations of arsenic and uranium with reference to the new concentration standards and to the classifications of the bedrock geologic units (hereafter bedrock units) in which the wells are drilled. The results can be used to establish statistical probabilities for elevated concentrations by bedrock unit, which can guide future well-water testing, treatment, and supply development.

Purpose and Scope

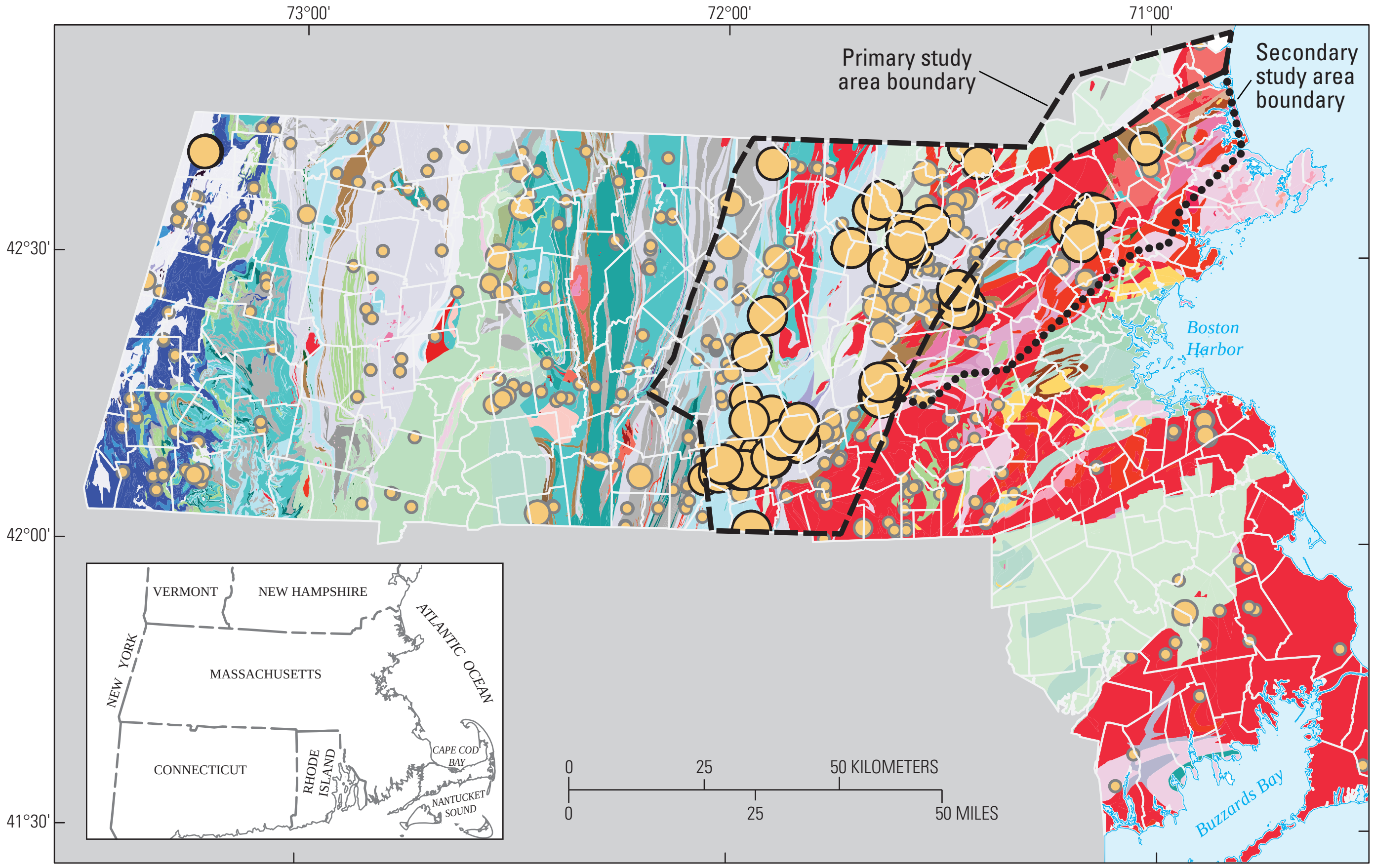
Information about bedrock associations of arsenic and uranium with bedrock well water are needed in Massachusetts to guide future well-water testing, treatment, and supply development. Probability distributions of well-water contaminants by bedrock unit will indicate the likelihood of contamination at a given concentration. Maps of these probabilities can be used to determine the likelihood of the presence of elevated arsenic or uranium concentrations in water of new wells in a given location or for directing testing priorities for existing wells.

The study encompasses the east-central arsenic belt in Massachusetts (fig. 1), the location of nearly all contamination of bedrock wells in the State by arsenic from a natural source. Many but not all wells contaminated by uranium are included in the same area, although igneous rocks, and likely uranium contamination, also occur outside the arsenic belt.

The principal focus of this report is the collection and interpretation of new data from 478 private bedrock wells. The amount of existing unpublished MDEP data from public bedrock wells is large, however, and may substantially supplement the number of observations per bedrock unit. The public bedrock-well data were used for qualitative analysis of the extent of contamination of bedrock units. The newly collected data were used to compute statistics of contaminant distribution. A reporting goal is to produce maps showing the probability statistic that concentrations of arsenic or uranium in well water exceed the drinking-water standards.

Health Effects of Arsenic and Uranium

Health effects from exposure to elevated concentrations of arsenic in drinking water have been established from studies in countries with very elevated levels of arsenic in water supplies, especially Taiwan (Smith and others, 1992; Lamm and others, 2003). Inorganic arsenic is well documented as a human carcinogen of the bladder, lungs, and skin (Centeno and others, 2007). Inorganic arsenic has also been demonstrated to affect many other organ systems, including the gastrointestinal, hepatic, cardiovascular, nervous, renal, and hematopoietic systems. A recent interest in arsenic in drinking water in the northeastern part of the United States relates to possible correlations with increased rates of bladder cancer in the region (Devasa and others, 1999; Ayotte and others, 2006). Epidemiological results demonstrating links between arsenic and health problems involve concentrations greater than the current USEPA drinking-water standard by an order of magnitude or more (National Research Council, 2001). Risk levels at



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

EXPLANATION

🟥 **Town boundary**

Arsenic, in micrograms per liter—Black-border symbols indicate concentrations greater than the U.S. Environmental Protection Agency public drinking-water standard

- ● < 1
- ● 1 – < 5
- ● 5 – < 10
- ● 10 – < 20
- ● 20 – 1,000

Figure 1. Arsenic concentrations in public bedrock wells in Massachusetts, 2008. Data from the Massachusetts Department of Environmental Protection. See figure 3 and appendix 1 for explanation of bedrock units in the east-central part of Massachusetts. <, less than

the standard are determined by extrapolation from the higher exposure studies. The National Research Council review for the National Academy of Science estimated the bladder cancer risk at about 12 to 23 per 10,000 persons with lifetime consumption of drinking water at 10 µg/L, the current public supply drinking-water standard. Lung cancer risk is estimated at about 14 to 19 per 10,000 persons at 10 µg/L (National Research Council, 2001).

Little is known about the long-term health effects on humans of exposure to low-level environmental uranium. Studies of occupationally exposed persons, such as uranium miners, have shown that the major health effect of uranium in the body is renal (kidney) toxicity (Leggett, 1989; Taylor and Taylor, 1997).

A discussion of the health effects of uranium in New England can also consider the effects of radium and radon, which are associated with uranium in crystalline bedrock aquifers (Ayotte and others, 2007). The association arises from the radioactive decay chain of uranium, which results in radium, through several radioactive decay product precursors. Radium decays directly to short-half-lived radon (3.8 days). Decay of radon results in four short-lived daughters and then longer-lived lead (22 years). Where uranium in drinking water is measured greater than the standard, analyses for radium and radon also could be done. Depending on the analysis technique, differential costs of analyses of the radionuclides means that uranium analysis may be an inexpensive indicator (when compared to gross alpha analysis) for determining the presence or absence of other radionuclides.

Previous Investigations

Several previous water-quality investigations exist for arsenic in New England and areas of Massachusetts. Investigations of uranium are more limited and cover the entire Northeast. The first published investigation to address the concerns of arsenic concentrations in private bedrock wells of New England referred to southeastern New Hampshire (Boudette and others, 1985). Bedrock and anthropogenic sources were analyzed, and the conclusion was drawn that the source was probably anthropogenic. A similar investigation of arsenic wells in Buxton, Maine, concluded that the likely source was bedrock (Marvinney and others, 1994). A three-town investigation in southern New Hampshire, very similar to the present Massachusetts investigation, reported the percentages of arsenic samples with concentrations greater than the 10 µg/L standard by bedrock unit (Montgomery and others, 2003). Several New England-based investigations have evaluated the risk for arsenic occurrence in the region—number of wells affected and probability maps of concentrations greater than or equal to 5 µg/L (for example, Karagas and others, 2002; Ayotte and others, 2003; 2006). Ayotte (2006) used a logistic regression based on many geologic, hydrologic, and anthropologic statistics for the region. A nationwide investigation of contaminants in private wells of selected aquifers included distribution plots of arsenic concentrations for the New England bedrock aquifer (DeSimone, 2009). The New England aquifer was the only aquifer investigated in the eastern United States with elevated concentrations of arsenic in private wells.

One survey of arsenic in private wells from Massachusetts is available from an investigation in Pepperell, Massachusetts (SEA Consultants, 1985). Water was analyzed from 300 wells, and 12 percent of them had concentrations that exceeded the 50-µg/L USEPA standard that was in effect at that time. Attempts to distinguish natural sources of arsenic in bedrock from anthropogenic sources, such as pesticides applied to orchards, were not successful.

Finally, a geologically based review of arsenic presence in the Northeast was published by Peters (2008). The investigation discusses arsenic presence in overburden and bedrock wells from natural and anthropogenic sources. Peters (2008) showed that arsenic concentrations were not correlated with iron concentrations in bedrock well water, and that elevated arsenic concentrations were associated with contacts between metamorphic and intrusive igneous rock.

Uranium was included in the DeSimone (2009) survey of private wells, including several overstandard samples in the New England crystalline-rock aquifers, but the study involved few samples from Massachusetts. In an investigation summarizing uranium and radon data from the northern United States, a correlation was found between uranium, radium, and radon in the New England bedrock aquifer (Ayotte and others 2007). Of the nine northern aquifers investigated, median concentrations of radon and uranium were highest and third highest, respectively, in the New England bedrock aquifer.

Investigative Design

The investigative design followed that of Montgomery and others (2003) in southeastern New Hampshire, addressing the correlations between bedrock units and concentrations of arsenic and uranium. The intent in this study was to cover the known elevated-arsenic areas in Massachusetts so that the assessment of arsenic contamination in the State would be advanced as much as possible. However, future studies may be necessary to characterize other parts of the State with limited areas of elevated arsenic.

Study Area

The primary study area (fig. 1), in east-central Massachusetts, was chosen to include the area of elevated results (greater than or equal to the USEPA drinking-water standard for public supplies, 10 µg/L) of arsenic in public wells (primarily bedrock) published from the MDEP database (Ayotte and others, 2003). Data reviewed after initiation of the project (J.A. Cerutti, Massachusetts Department of Environmental Protection, written commun., 2008; Ayotte,

2006) indicated additional elevated concentrations to the east of the principal study area and one elevated value in the northwest (fig. 1). The primary study area was augmented with a secondary study area (fig. 1) to cover the elevated concentrations in the east. By including the areas of known elevated concentration, the investigation would define arsenic occurrence in the principal areas of Massachusetts where concentrations could be expected to exceed the drinking-water standard.

Although the project study areas were determined on the basis of concentrations of arsenic in bedrock wells, the areas were also appropriate for investigation of uranium (fig. 2). MDEP data show that the arsenic-defined areas include many of the elevated concentrations of uranium in the State. The MDEP uranium coverage is less extensive than that for arsenic, so uranium concentrations are unknown in some areas. Not all of the bedrock units that may have elevated uranium were characterized in the present investigation; however, enough elevated-concentration units were included that correlations between uranium and bedrock unit would be apparent if uranium were controlled by rock type.

The distribution of bedrock units of crystalline igneous and metamorphic rocks in the study area is complex (fig. 3). The study area is crossed by major faults that divide parts of three geologic terranes that include the Merrimack belt, the Nashoba zone and the Milford-Dedham zone (Hatch, 1991, p. v, fig. 2). The primary study area includes most of the Merrimack belt, which extends from the Connecticut Valley belt (indicated by the Merrimack belt western boundary in fig. 3) to the Clinton-Newbury fault (fig. 3), and the western half of the Nashoba zone, which extends from the Clinton-Newbury fault to the Bloody Bluff fault (fig. 3). The secondary study area includes the remainder of the Nashoba zone and the western edge of the Milford-Dedham zone, which begins at the Bloody Bluff fault and extends to the east.

Geologic units are as defined in the digitized version (Nicholson and others, 2007) of the bedrock map of Massachusetts (Zen and others, 1983). The use of these maps to define geologic units for wells is, of course, only as accurate as could be determined from a 1:250,000-scale map. There is the chance that wells near a bedrock boundary may not be correctly assigned to a bedrock unit. Bedrock wells are on the order of 100 m deep and unscreened in their bedrock portions. As such, they may encounter geologic units at depth that are different from units as mapped at the surface. But, due to the scale of the map (1:250,000), only the major rock type is shown at the location of the borehole. For example, a borehole study in a 305-m deep well in Tyngsborough, Mass., is located in the Ayer Granite bedrock unit SOad, but the borehole contains xenoliths of the host metasedimentary Berwick Formation (unit Sb) (Pierce and others, 2007). The level of detail seen in boreholes cannot be displayed on a State-scale map, and detailed studies of individual boreholes are beyond the scope of this regional study.

Sampling Distribution

Well locations were chosen for the study areas by stratified random selection across the bedrock units. Previous arsenic-concentration data (Ayotte and others, 2003; Joseph Cerutti, unpub. data, 2008) indicated that arsenic was more prevalent in the 69 bedrock units of the primary study area, so more sampling was directed at this area. One sampling objective was to collect at least seven samples per bedrock unit so that statistical inference could be made even for small units. So that large units would have coverage throughout their extent, a second objective was applied to supplement the initial seven samples by an additional one sample per 20 km^2 for units 20 km^2 and larger. The largest unit, the Paxton Formation (Sp), is 822 km^2, so the sampling objective for this unit was 48 wells. In the secondary area, the selection objective was 5 wells for each of the 12 bedrock units investigated.

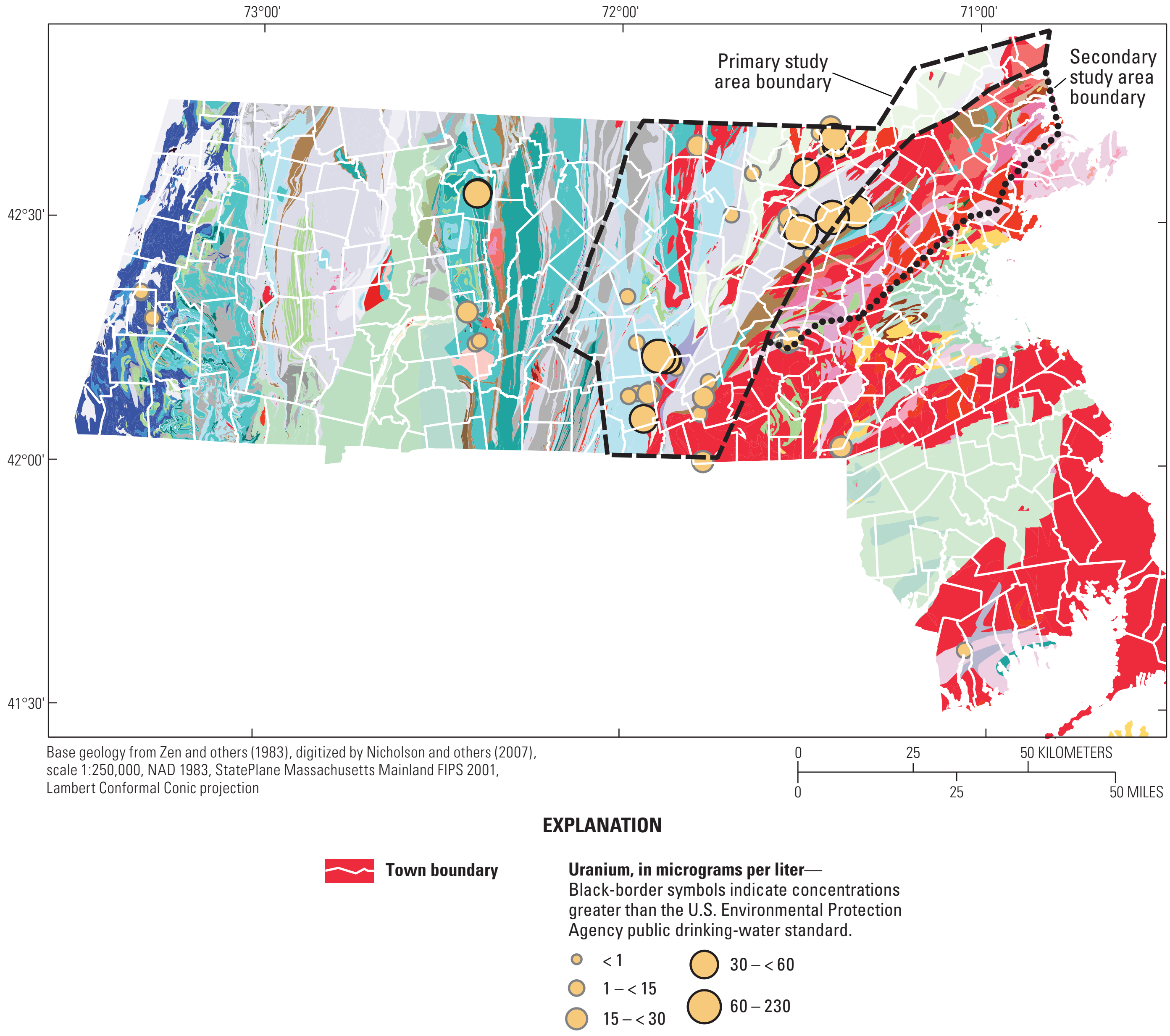
Although a minimum of seven sites per unit in the primary study area was desired, some small units did not have this number of private wells (or even residences) available. Also, areas with public water supplies were necessarily excluded from the investigation, which left gaps in data for some units. These unavoidable exclusions of sampled areas biased the study toward areas where bedrock wells existed.

Wells were selected using randomly generated geo-coordinates and matching closest Google-Earth determined locations of well addresses to well lists provided by the Massachusetts Department of Conservation and Recreation. Locations of the selected sites were moved from the street locations provided by Google Earth to positions of the building at that address using field observations of addresses and buildings, and georeferenced ORTHO photos (Massachusetts Office of Geographic Information (MassGIS), 2005).

Increased sampling in the investigation was directed in the regions of three 1:24,000 (7.5 minute) quadrangles where recent detailed geologic mapping had been conducted. Comparisons of correlations of arsenic and uranium with geologic units based on 1:250,000-scale mapping to those based on more recent 1:24,000-scale mapping could indicate the efficacy of remapping for arsenic and uranium delineation and for correlation with bedrock.

Sample Collection and the Well-User Questionnaire

Samples were collected by private well users during spring and summer of 2009, using bottles included in a sampling kit mailed to the residence at the location of the well. The kit included two labeled 125-mL bottles, a business reply Tyvek® envelope, and a questionnaire to determine water-use practices at the site, as well as to inform the bottle recipients about the program and how to collect the water sample (app. 2). Twice as many sampling kits were mailed out compared to the number required to meet the sampling



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 2. Uranium concentrations in public bedrock wells in Massachusetts, 2008. Data from the Massachusetts Department of Environmental Protection. See figure 3 and appendix 1 for explanation of bedrock units in the east-central part of Massachusetts. <, less than

objective for each rock type. A 50-percent return rate was expected, based on return rates from a similar investigation in New Hampshire (Montgomery and others, 2003). Well users were given 1 month to reply before a followup card was sent. If no reply had been received by 2 months after the followup card, the site was dropped from the study.

Sample Processing and Analytical Methods

All samples were collected by the residents living at the addresses selected for sampling. The samples were returned in a Tyvek® envelope by mail to the USGS office in Northborough, Mass. Samples intended for trace-constituent analysis were acidified to a pH less than 2 in the Northborough laboratory with 0.4-mL analytical-grade concentrated nitric acid (HNO_3). The acidified samples were sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., for analysis as listed in table 1. At the laboratory, samples were subject to an in-bottle acid digestion before analysis so that results represented total constituent values.

Supplemental Data

Additional data (1997 to 2007) on arsenic and uranium in bedrock wells were retrieved from the database of the MDEP (Joseph Cerutti, unpub. data, 2008) (figs. 1 and 2). The data were from analyses of water in public wells and were screened to include only data from bedrock wells. Although the results likely were relevant to the investigation, some differences prevented a simple combination of the data with that collected during this investigation. Different and multiple laboratories (State certified) were used for the analyses for MDEP data than were used for the USGS data. Greater water use may be expected from the public wells in the MDEP database compared to the private wells in the USGS database. The MDEP data were used to help define the areal distribution of arsenic and uranium but were not used in statistical summaries of occurrence of these constituents.

Statistical Comparisons

Parametric statistical tests were used, which are appropriate if normality or any other specific distribution (log normal in this investigation) can be assumed (Iman and Conover, 1983). Analysis of associations of concentration with bedrock unit was determined by one-way analysis of variance (ANOVA) on log-transformed concentration data, using the statistical software package Minitab 16®. Cumulative distribution functions with 95-percent confidence intervals were determined for concentration populations grouped by bedrock unit by fitting data to a log-normal distribution, using the statistical software package Minitab 16® with the options for distribution analysis, and arbitrary data censoring. For bedrock units with fewer than five analyses with concentrations exceeding the analytical reporting limit, the option to assume a common scale was used in the distribution fitting.

The statistical software package SPLUS® was used to compare geologic mapping techniques and the correlation with arsenic and uranium concentrations. The comparisons were made with a multiple linear regression of log-transformed data.

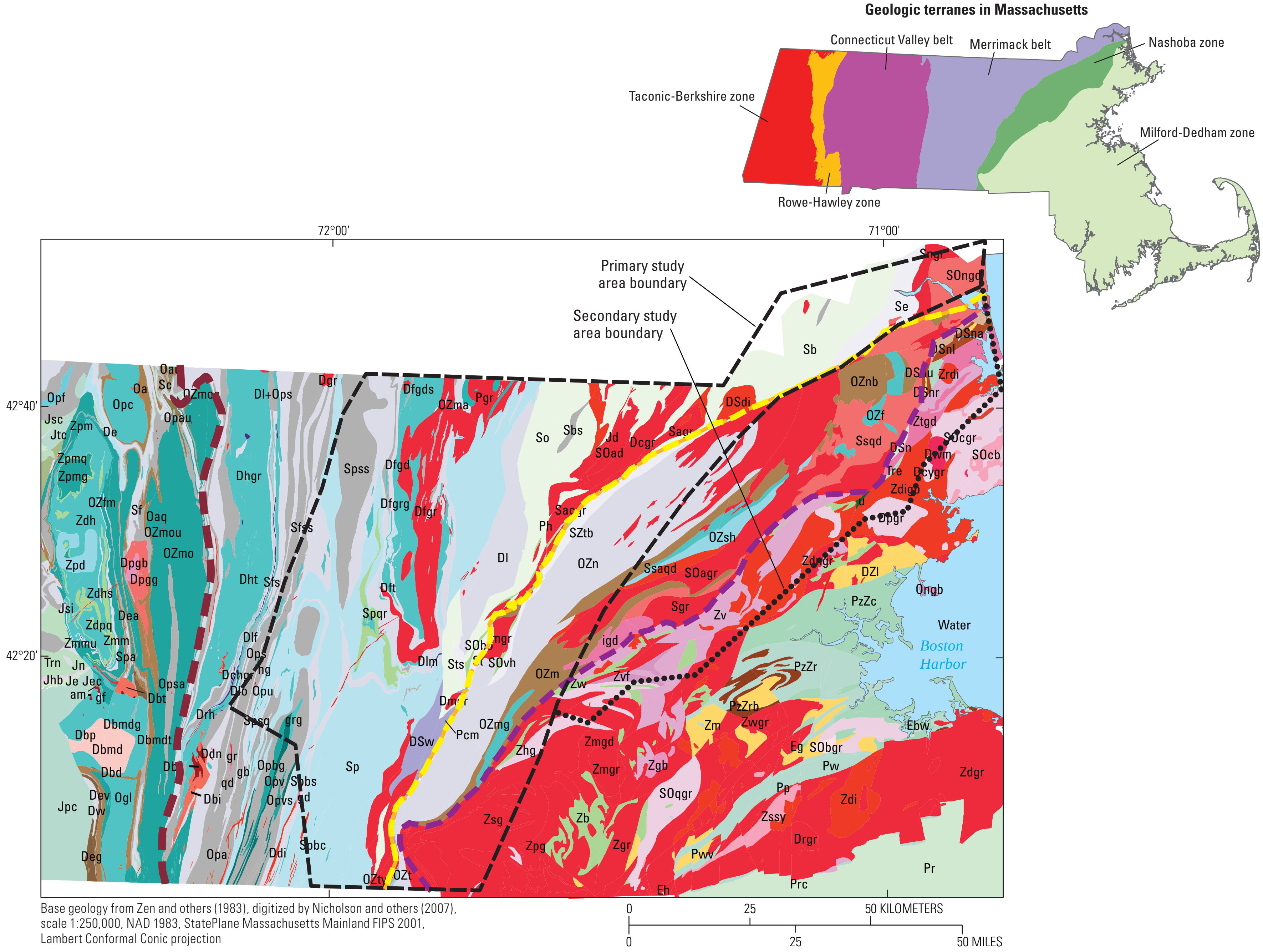
Arsenic and Uranium Concentrations and Correlations with Bedrock Units

The ranges and correlations of arsenic and uranium concentrations among bedrock units are the focus of this project. The project objective is to use the correlations to guide future well-water testing, treatment, and supply development.

Quality Assurance and Other Data Attributes

During the investigation, 60 quality-assurance samples were analyzed for iron, manganese, arsenic, and uranium. The quality-assurance samples included sampling-bottle and preservation-acid blanks, a standard-reference sample, resampling, duplicate sampling, and sample splits (table 2). Quality-assurance results of the blank samples showed that possible contamination did not occur during sampling, during sample handing, or from sampling materials (the bottles and preservation acid). All concentrations measured for the four sampling-bottle blanks during the study were below the reporting limits (table 1) for the respective analytes (table 2). Four samples of standard reference solution (USGS T-195) submitted to the NWQL as blind samples were generally within 5 percent of the known values. Average percent errors (average, in percent, of the absolute difference between replicate pairs divided by the average of the replicates) increased for all elements in the comparison series: split samples, duplicate samples separated by 5 minutes, and duplicate samples separated by months (average interval of 80 days). The error increase reflected variability in samples over time—small, but measureable for samples collected within 5 minutes, and larger for samples collected months apart.

Variability of concentrations over time was investigated by analysis of 48 duplicate samples. USGS personnel visited 12 randomly chosen wells where three samples were collected at each well: duplicate samples within 5 minutes and a third sample to compare with the original sample collected by the well user. Results showed that repeatability for samples collected sequentially at one visit was very good, but that substantial variation can occur for a well sampled over time (fig. 4). Sampling error from additional sources is possible in resampling over time, including the possibility of sampling from different water taps by mistake.



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

EXPLANATION

	Rock type	Bedrock
■	alkali-granite (alaskite)	Dcygr Dpgr SOcgr SOqgr Zagr Zhg
■	amphibolite	am Dea Oa Opa OZm OZmoa OZnb Spa
■	andesite	DSna
■	argillite	Ebw Eh PzZc
■	arkose	Jm Jn Trn
■	augen gneiss	Opau
■	basalt	DSnl
■	biotite gneiss	Opau Opvs OZfm OZmo Zpm Zpmg
■	calc-silicate rock	Sfs
■	conglomerate	Jec
■	dacite	Dbd
■	diabase	Jd
■	diorite	Ddi Ddn di DSdi Ssaqd Zdi Zdigb Zrdi
■	felsic gneiss	Dlf Opf
■	felsic metavolcanic rock	Zvf
■	gabbro	Dpgb gb Ongb Zgb
■	gneiss	Drh OZsh OZtf Zpd
■	granite	Dcgr Cmgr Drgr gr mgr Pgr Sacgr Sagr Sgr Sngr SOad SOagr Zdgr Zdngr Zgr Zmgd Zmgr Zpg Zsg Zwgr
■	granitic gneiss	Dbmdg Dchgr Dfgd Dfgds Dfgrg Dhgr Dht grg Ogl Opc OZf OZmg Zdh
■	granodiorite	Dgd gd igd Ztgd
■	granofels	De gf Sf Sp Spbc Spbs
■	granulite	Deg
■	hornblendite	Dbh Oau
■	mafic gneiss	Dchh Dlo hg Opv
■	mafic volcanic rock	PzZrb
■	marble	Dlm
■	metasedimentary rock	Sb So
■	metavolcanic rock	Zv
■	mica schist	Dev Dl+Ops Ops Opsa OZty Sbs Sfss
■	monzonite	Dwm
■	mudstone	DSnu
■	mylonite	Jfg
■	paragneiss	OZma
■	pegmatite	Dpe
■	peridotite	Dbp OZmou Zmmu
■	phyllite	Dgm Se SObo Sts SZtb
■	porphyry	SObgr
■	quartz diorite	Dbi
■	quartz monzodiorite	Dbmd Dbmdt
■	quartzite	Eg Oaq PZfmg SOvh Soqr St Zb Zdpq Zpmq Zw
■	rhyolite	DSnr DZl Pwv Zm
■	sandstone	Je Jsm Jt Pr Prc
■	schist	Dl Dw OZn OZt Spsq Zdhs Zmm
■	sedimentary breccia	Jma
■	sedimentary rock	DSn
■	serpentinite	u
■	slate	DSw Pcm
■	syenite	SOcb Zssy
■	tonalite	Dbt Dft Dpgg SOngd Ssqd
■	tuff	Jgb
■	ultramafic intrusive rock	Opu

▬ ▬ **Merrimack belt western boundary**

▬ ▬ ▬ **Bloody Bluff fault**

▬ ▬ ▬ **Clinton-Newbury fault**

Figure 3. Bedrock units and principal faults in the project study area of east-central Massachusetts. See appendix 1 for explanation of bedrock units. Map colors from Moyer and others, 2005.

Table 1. Chemical analytical methods used in the arsenic and uranium study, east-central Massachusetts, 2009.

[NWQL, U.S. Geological Survey National Water Quality Laboratory, Denver, Colo.; NA, not applicable; ºC, degrees Celsius]

Constituent	Units	Method	Reporting limit	Method reference
Acid neutralizing capacity	Milligrams per liter as calcium carbonate	Auto titrator at the USGS Northborough lab	NA	Rounds, 2006
Conductance	Microsiemens per centimeter at 25 °C	Orion conductance probe at the USGS Northborough lab	NA	Radtke and others, 2005
pH	pH log units	Initial pH from alkalinity titration at the USGS Northborough lab	NA	Ritz and Collins, 2008
Arsenic	Micrograms per liter	In-bottle acid digestion followed by collision/reaction cell inductively coupled plasma/collider mass spectrometry at NWQL	0.2	Garbarino and others, 2006; Garbarino and Struzeski, 1998
Iron	Micrograms per liter	In-bottle acid digestion followed by inductively coupled plasma-atomic emission spectroscopy at NWQL	14	Garbarino and others, 2006; Garbarino and Struzeski, 1998
Manganese	Micrograms per liter	In-bottle acid digestion followed by inductively coupled plasma/collider mass spectrometry at NWQL	0.4	Garbarino and others, 2006; Garbarino and Struzeski, 1998
Uranium	Micrograms per liter	In-bottle acid digestion followed by inductively coupled plasma/mass spectrometry at NWQL	0.02	Garbarino and others, 2006; Garbarino and Struzeski, 1998

Return Rates for the Water Samples

Of the total 1,580 sample kits sent to well users, samples from 478 wells were returned, a 30-percent return rate. The low return rate resulted in several bedrock units that had too few samples for statistical analysis.

Water Use and Water Quality at Sampled Wells

Results from the returned questionnaires indicate that 91 percent of the respondents use their well water for drinking. Many users treat the water in some way including softening, radon removal, arsenic removal, and reverse osmosis. Of the respondents with wells having arsenic concentrations exceeding the drinking-water standard, however, 66 percent were using water for drinking without treatment. Of the respondents with wells having uranium concentrations exceeding the standard, 93 percent were using water for drinking without treatment. The statistic included one respondent that was not using the water for drinking because it had not been tested. Thus, none of the respondents with wells having uranium concentrations exceeding the standard were treating the water for uranium removal.

Arsenic Concentrations

Arsenic concentrations in the complete dataset ranged from less than 0.2 µg/L (less than the laboratory reporting limit) in 24 percent of all samples tested to 1,540 µg/L. Of the 344 randomly selected samples (excluding intensive quadrangle sampling), 13 percent exceeded the 10 µg/L drinking-water standard. For randomly selected samples from the primary study area, a slightly larger fraction of samples,

Table 2. Quality-assurance results for arsenic, iron, manganese, and uranium.

[USGS, U.S. Geological Survey]

Quality-assurance measure	Details	Number of samples	Result
Bottle blanks	Sample bottles had been sent out in mailers, and were preserved with acid	4	All concentrations were less than the method detection limit
Standard reference samples	USGS standard reference water sample, number T-195	4	Mean relative errors were Arsenic: 4.9 percent Iron: 2.4 percent Manganese: 0.62 percent Uranium: 5.6 percent
Sample splits	One sample split for two analyses	13	Mean relative errors were Arsenic: 3.8 percent Iron: 1.8 percent Manganese: 6.2 percent Uranium: 0.74 percent
Duplicates at one time	Samples collected sequentially on one sampling occasion	13	Mean relative errors were Arsenic: 5.8 percent Iron: 11.3 percent Manganese: 15.1 percent Uranium: 3.3 percent
Duplicates over time	Two samples collected on different sampling days	13	Mean relative errors were Arsenic: 49.5 percent Iron: 80.1 percent Manganese: 61.2 percent Uranium: 74.3 percent

15 percent, exceeded the standard. Concentrations of arsenic were not elevated in the 18 samples west of the primary study area, but some elevated concentrations were measured in the secondary study area, located east of the primary study area (fig. 5). Elevated concentrations can exist near low concentrations in the same bedrock unit, similar to distributions measured in other New England studies (Montgomery and others, 2003).

Arsenic Correlations with Bedrock Units

Arsenic concentrations in well water vary depending on the bedrock unit (fig. 6). Generally, concentrations are not narrowly distributed but rather extend above and below the median concentration for the bedrock unit by an order of magnitude or more. Although there are no bedrock units with elevated concentrations that do not also include low concentrations, there are some units with only low concentrations. One of the lowest-concentration units, Ops, is on the western edge of the study area, confirming the western limit to the elevated-concentration area in east-central Massachusetts. Each of the rock classifications of metamorphic, metamorphic with igneous intrusive, and igneous includes low-concentration and elevated-concentration units.

The variation within a bedrock unit indicates that median concentrations cannot be used for accurate predictions of concentrations in a unit. Concentrations in bedrock units are generally log normally distributed, so parametric statistical tests can be used to determine whether bedrock units and concentrations are related, or if distributions among bedrock units are significantly different. If a relation exists, probabilities of a bedrock well containing a given concentration may be calculated for each bedrock unit from cumulative distribution frequencies.

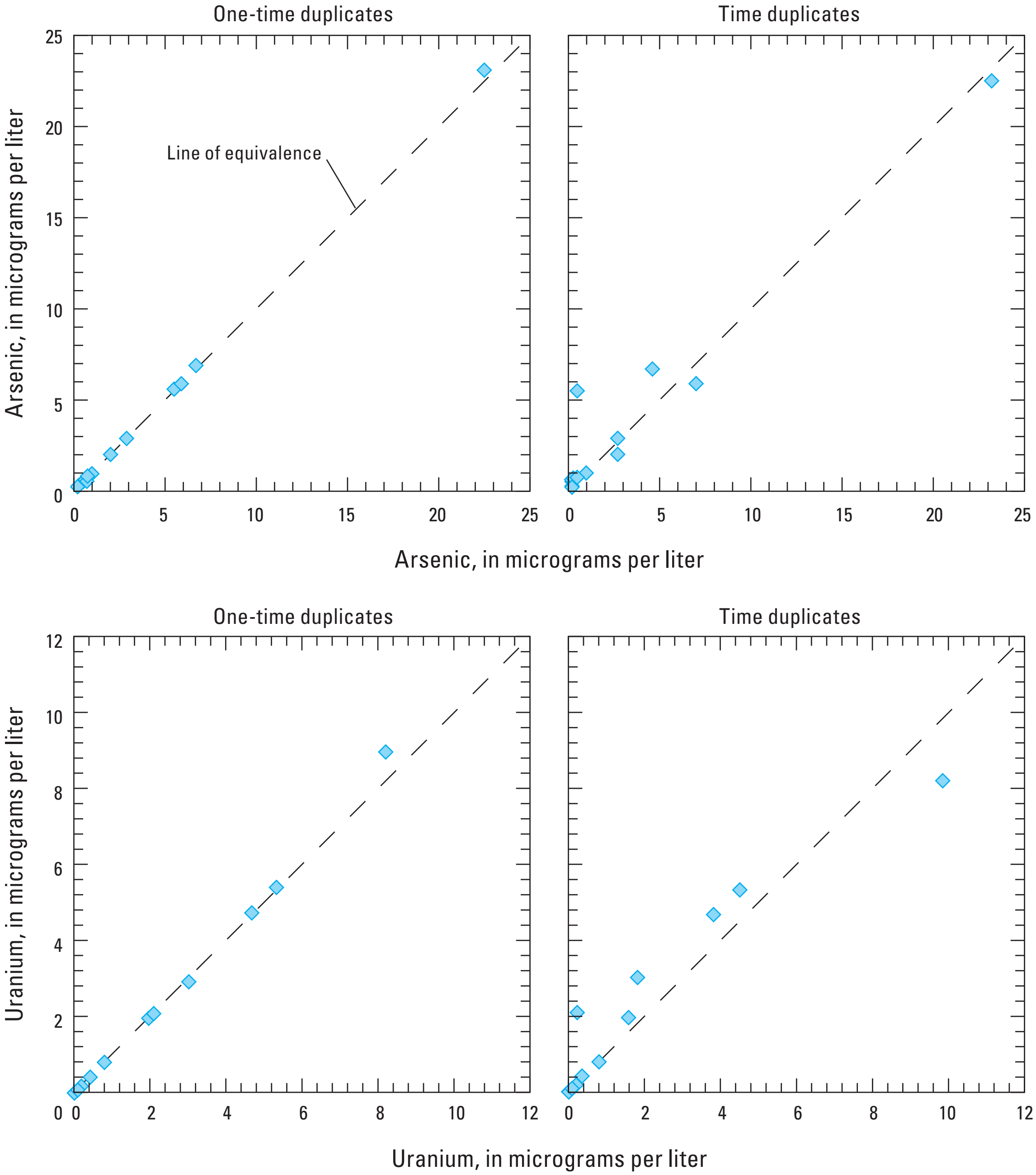
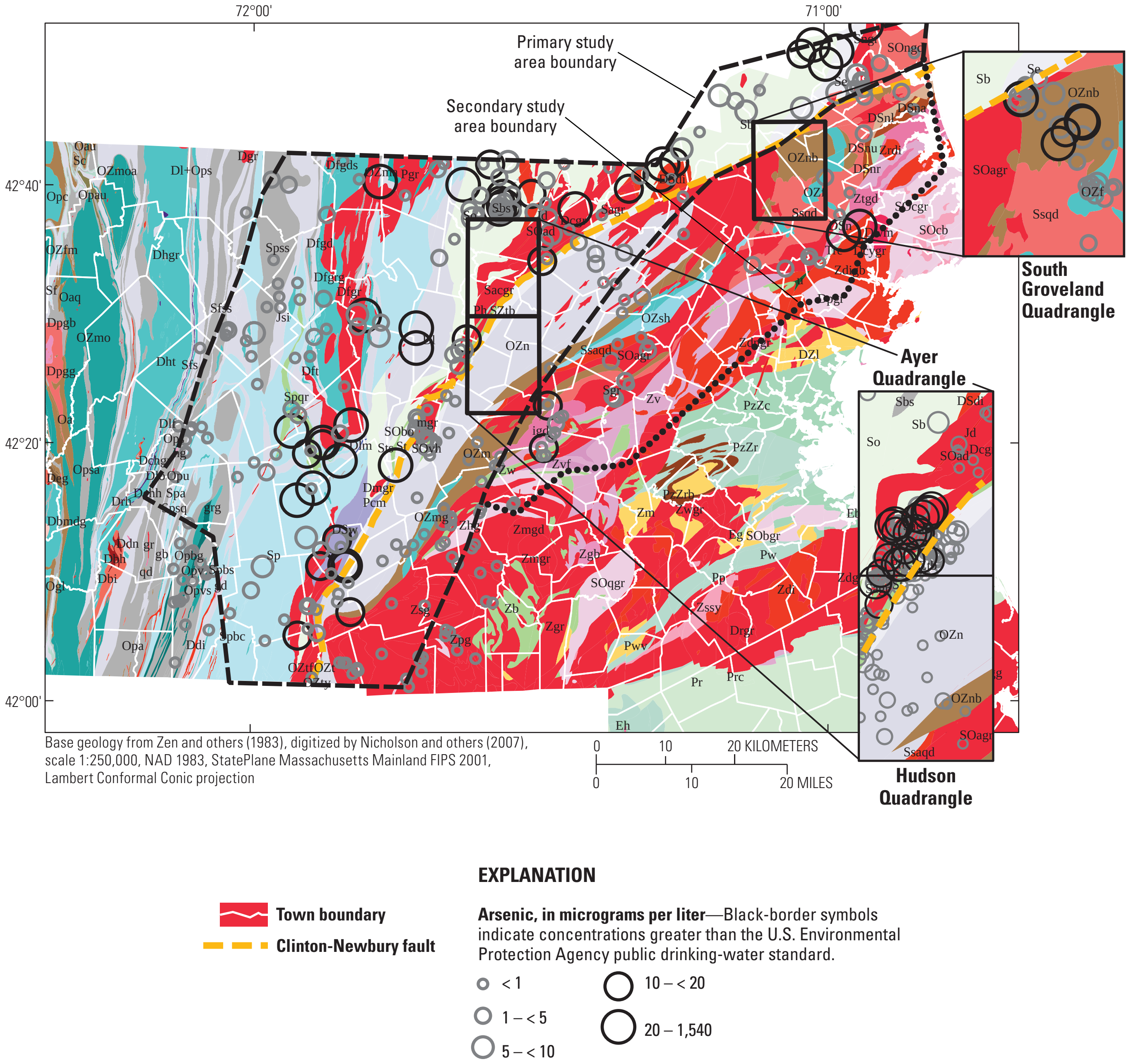


Figure 4. Arsenic and uranium sample duplicates collected on the same day and after about 80 days, east-central Massachusetts, 2009.



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 5. Arsenic concentrations in east-central Massachusetts, 2009. Sampling coverage was increased in the areas of the insert maps where geology was mapped at the 1:24,000 scale. See figure 3 and appendix 1 for explanation of bedrock units. <, less than

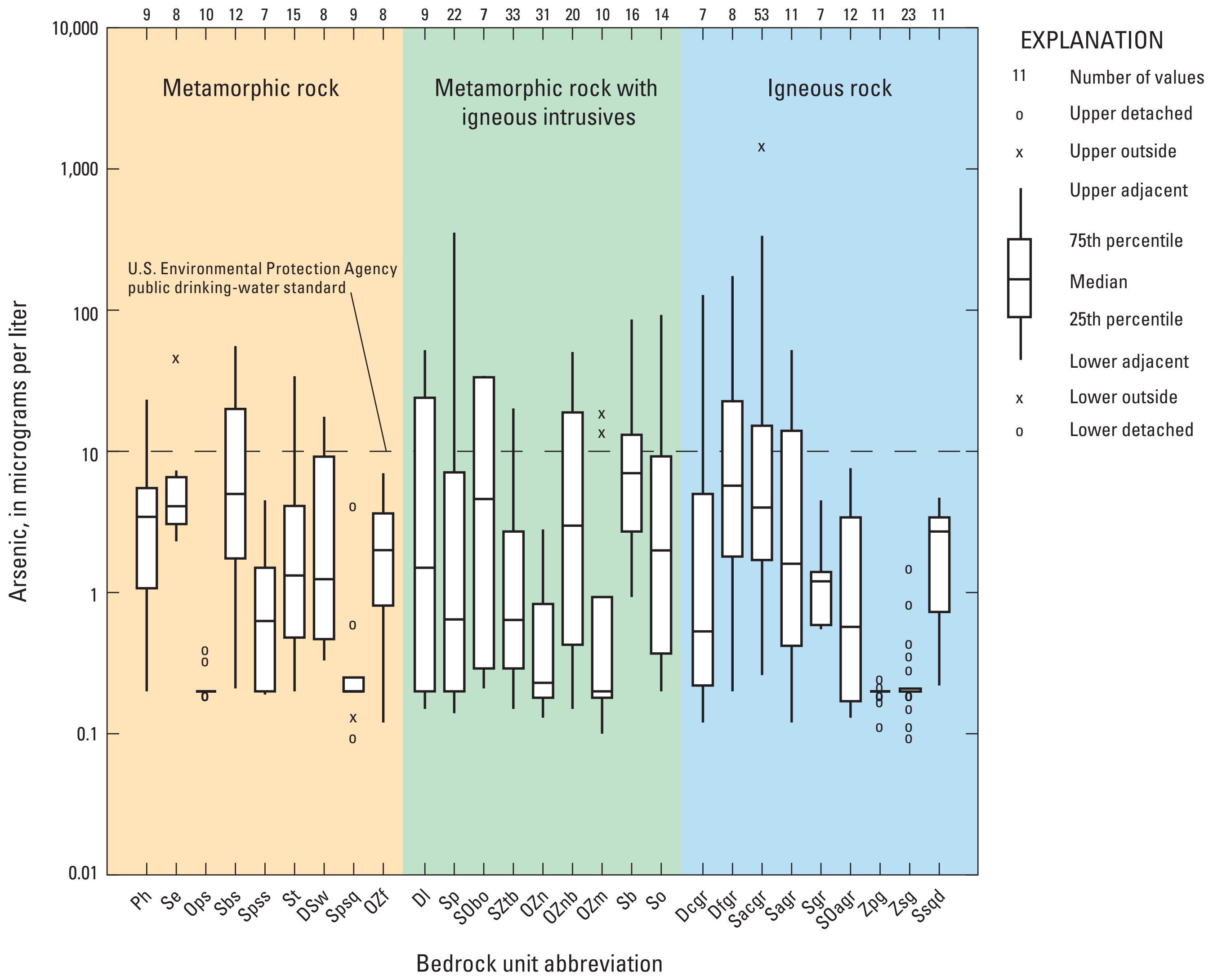
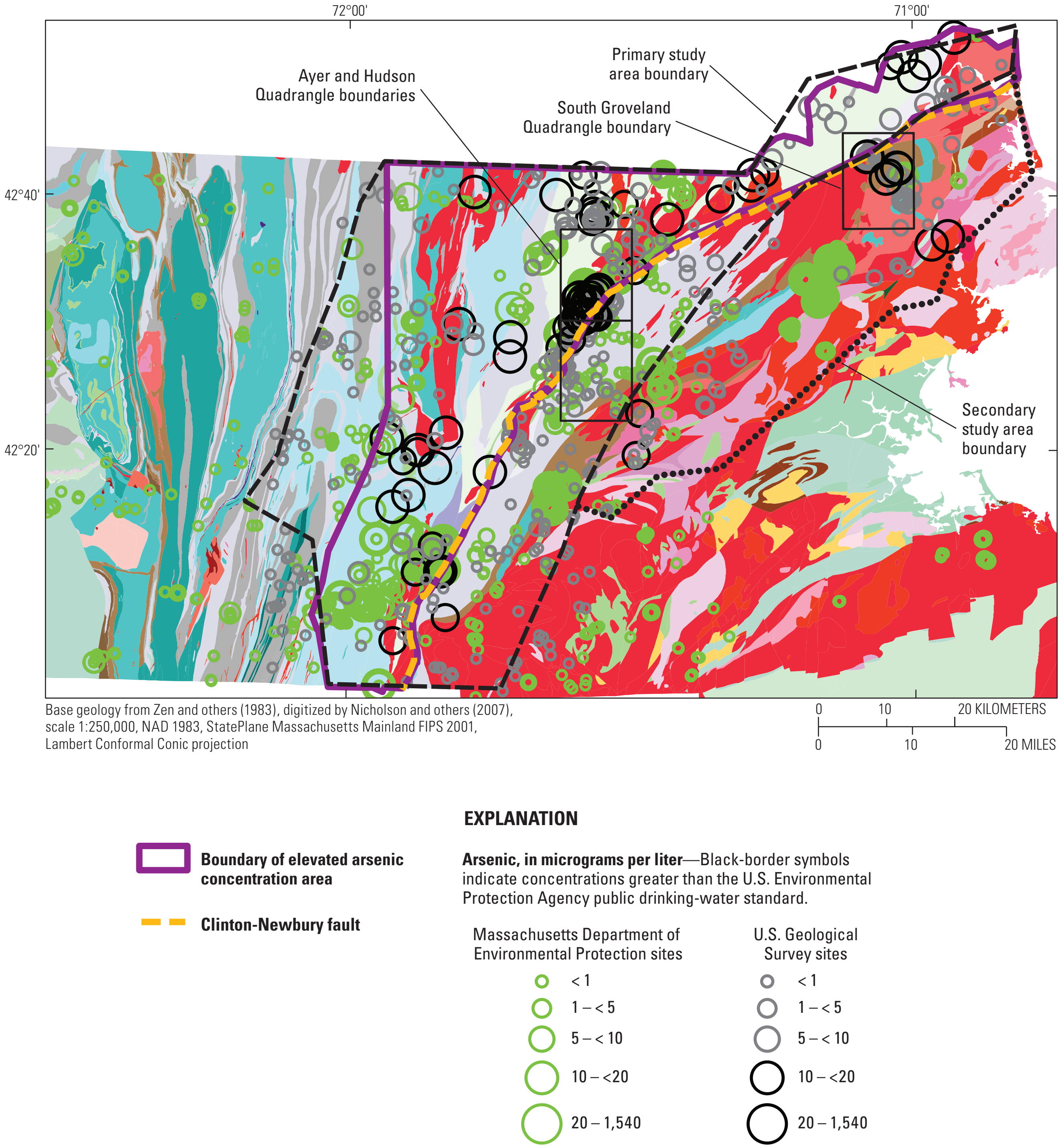


Figure 6. Distribution of arsenic concentrations by bedrock unit, with seven or more samples, in the primary and secondary study areas, east-central Massachusetts, 2009. See figure 3 and appendix 1 for explanation of bedrock units.

Arsenic concentrations north and west of the Clinton-Newbury fault are elevated (fig. 5). The fault marks a boundary between the Merrimack belt and Nashoba zone (fig. 3), and bedrock units do not extend across the fault boundary. The elevated arsenic concentrations extend approximately 20 km west and northwest of the fault. Within the 20-km zone, elevated concentrations were measured across a variety of bedrock unit rock types. Beyond the 20-km distance, sometimes within a rock type that has elevated concentrations near the fault, concentrations decrease. Lower concentrations of arsenic were measured in the large bedrock unit (OZn) east of the Clinton-Newbury fault. However, some elevated arsenic concentrations occur east of the fault, particularly in the OZnb unit.

An elevated-concentration area was defined as being bounded on the east by the Clinton-Newbury fault and extending westward to include all the concentrations measured greater than 10 µg/L (fig. 7). MDEP data were combined with the USGS data to define the western part of the elevated-concentration area. One-way ANOVA analysis was used to assess the relations between concentration and bedrock unit in the elevated-concentration area. Within the elevated-concentration area, there was no statistically significant difference at the 5-percent level between log-transformed concentration distributions, grouped by bedrock unit (fig. 8).



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 7. Arsenic concentrations, including Massachusetts Department of Environmental Protection data, showing elevated concentrations west of the Clinton-Newbury fault, east-central Massachusetts. <, less than

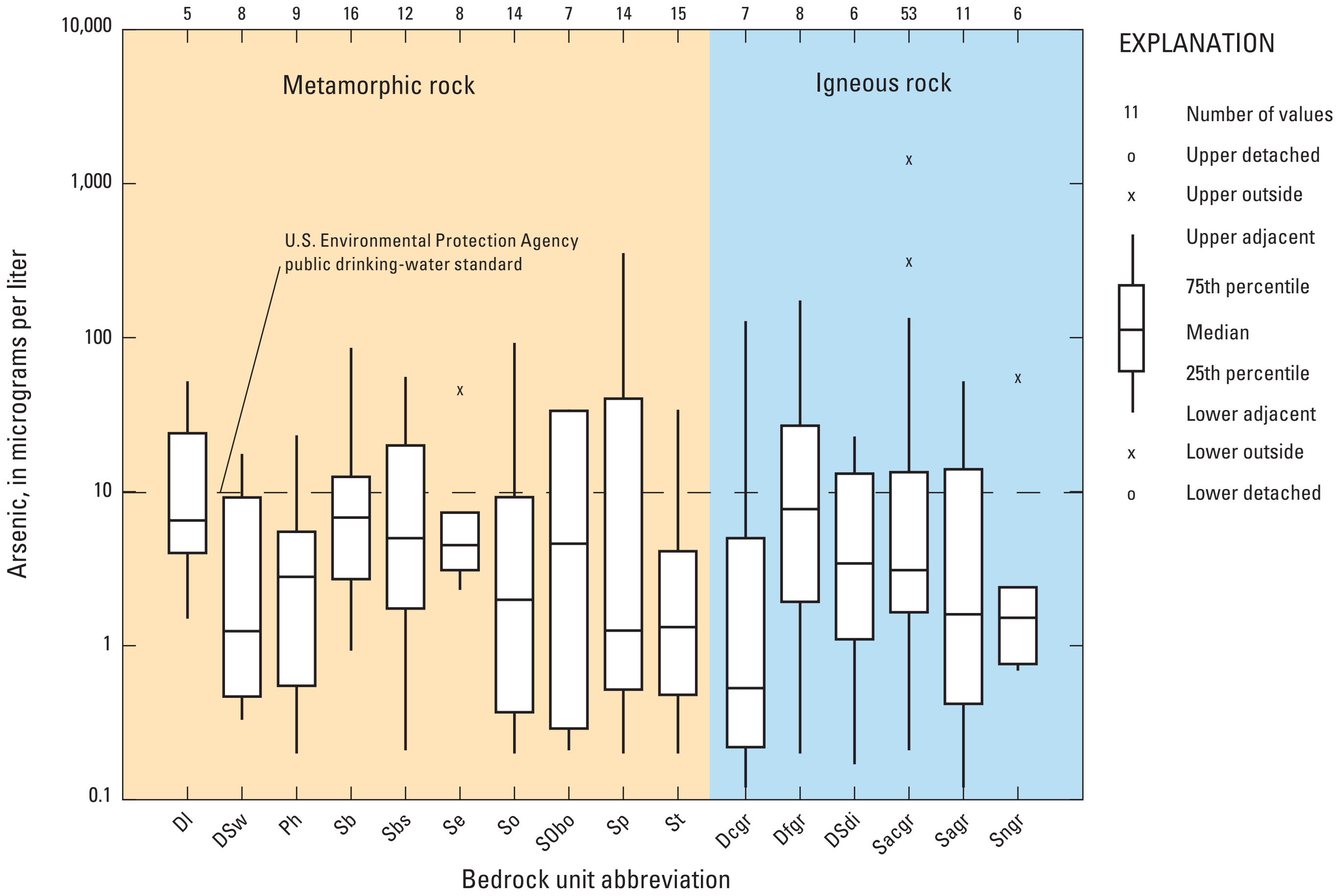
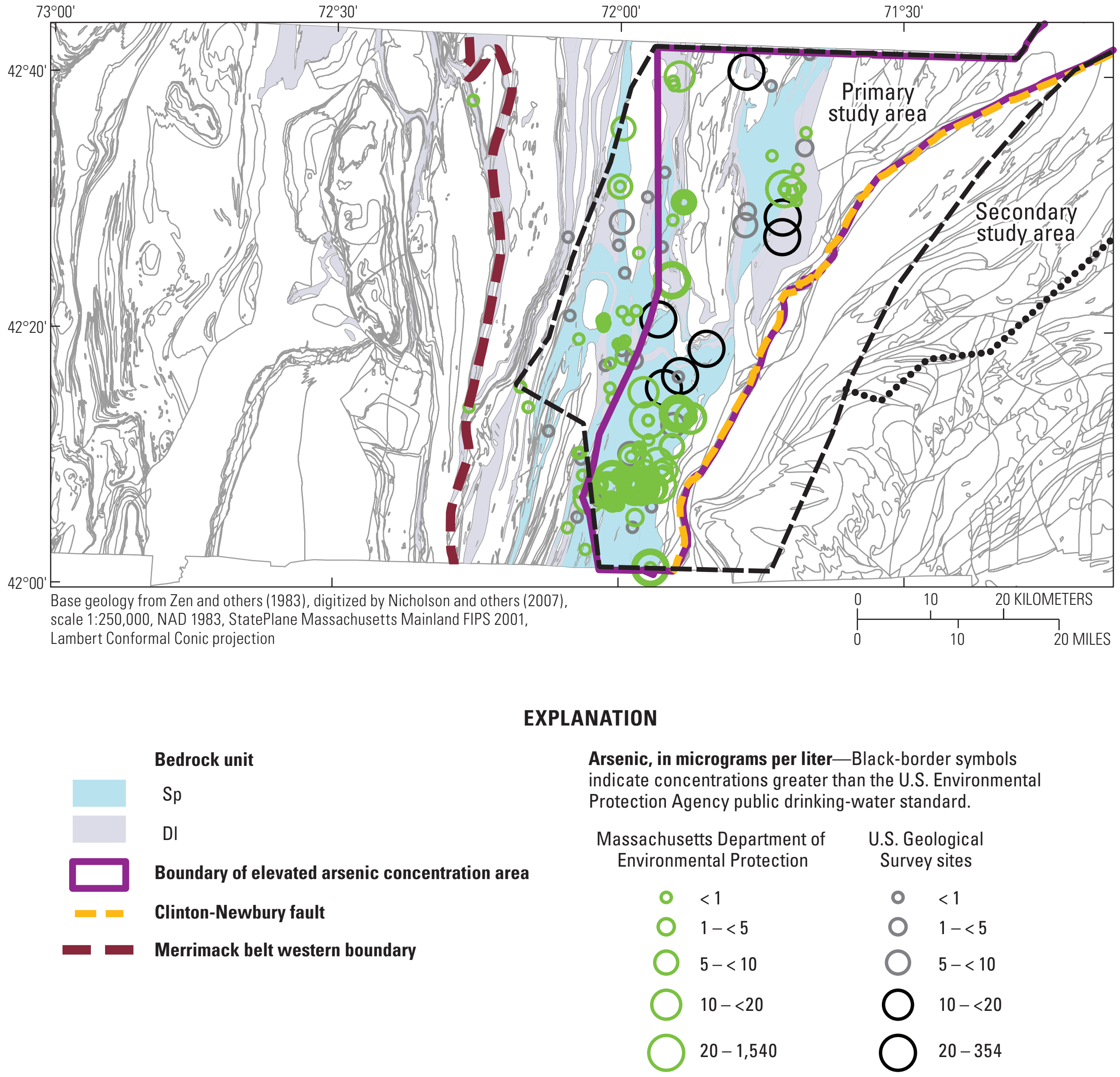


Figure 8. Distribution of arsenic concentrations by rock type in the elevated-concentration area, where differences in concentrations by unit were not significant, east-central Massachusetts. See figure 3 and appendix 1 for explanation of bedrock units.

Two of the bedrock units (Sp and Dl) inside the elevated-concentration area also extend outside the elevated-concentration area, where no concentrations exceeded the standard (fig. 9). Comparison of the data in the two units that cross the area boundary indicated that the difference across the elevated-concentration boundary, but within a bedrock unit, was statistically significant (fig. 10). These statistics indicate that the high-concentration area is within the Merrimack belt, but does not extend to the western boundary of the belt (fig. 9).

Three bedrock units with seven or more samples (Ops, Spss, and Spsq) were west or mostly west of the elevated-arsenic area. Concentrations in these bedrock units were significantly different from the grouped elevated arsenic area adjacent to the west.

A different pattern is observed east of the fault. Most striking is the difference between the bedrock unit SZtb, aligned with the Clinton-Newbury fault, and the bedrock unit OZn, adjacent to the east (fig. 5). Because of extra sampling in the area of the remapped quadrangles, there is an excellent



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 9. Arsenic concentrations inside and outside the elevated-arsenic area in bedrock units Dl and Sp. Data from the U.S. Geological Survey and the Massachusetts Department of Environmental Protection. See figure 3 and appendix 1 for explanation of bedrock units. <, less than

visual indication of arsenic concentration association with geology (inset map, fig. 5). One-way ANOVA analysis shows significant concentration differences between lower-concentration (OZn, Zhg, Zpg, Zsg, and Zw) and higher-concentration (SZtb and OZnb) units. The amphibolite-bearing rocks, OZnb, have elevated arsenic. Although not used for statistics, the MDEP dataset includes elevated concentrations in the southern parts of the amphibolite unit (fig. 7), which appears to indicate that the association is rock specific, not region specific as was found in the elevated concentration area in the west.

One-way ANOVA analysis of log-arsenic concentration in the rocks east of the Clinton-Newbury fault indicates that the arsenic concentrations in the OZnb unit are significantly higher than in the OZn unit (fig. 11). In this region east of the Clinton-Newbury fault, the mapped bedrock units indictate the distribution of arsenic concentrations. The OZnb unit extends well outside the primary study area and, as such, extends the area where elevated arsenic concentrations may be expected in Massachusetts from previous estimates (Ayotte and others, 2003).

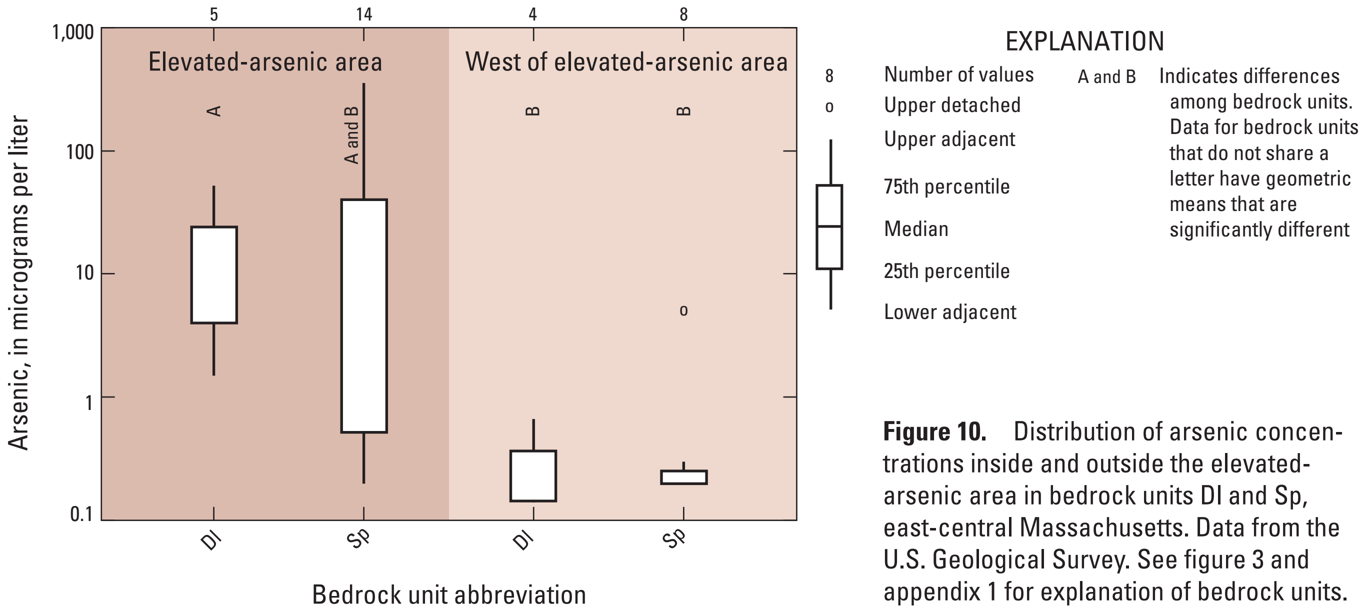


Figure 10. Distribution of arsenic concentrations inside and outside the elevated-arsenic area in bedrock units Dl and Sp, east-central Massachusetts. Data from the U.S. Geological Survey. See figure 3 and appendix 1 for explanation of bedrock units.

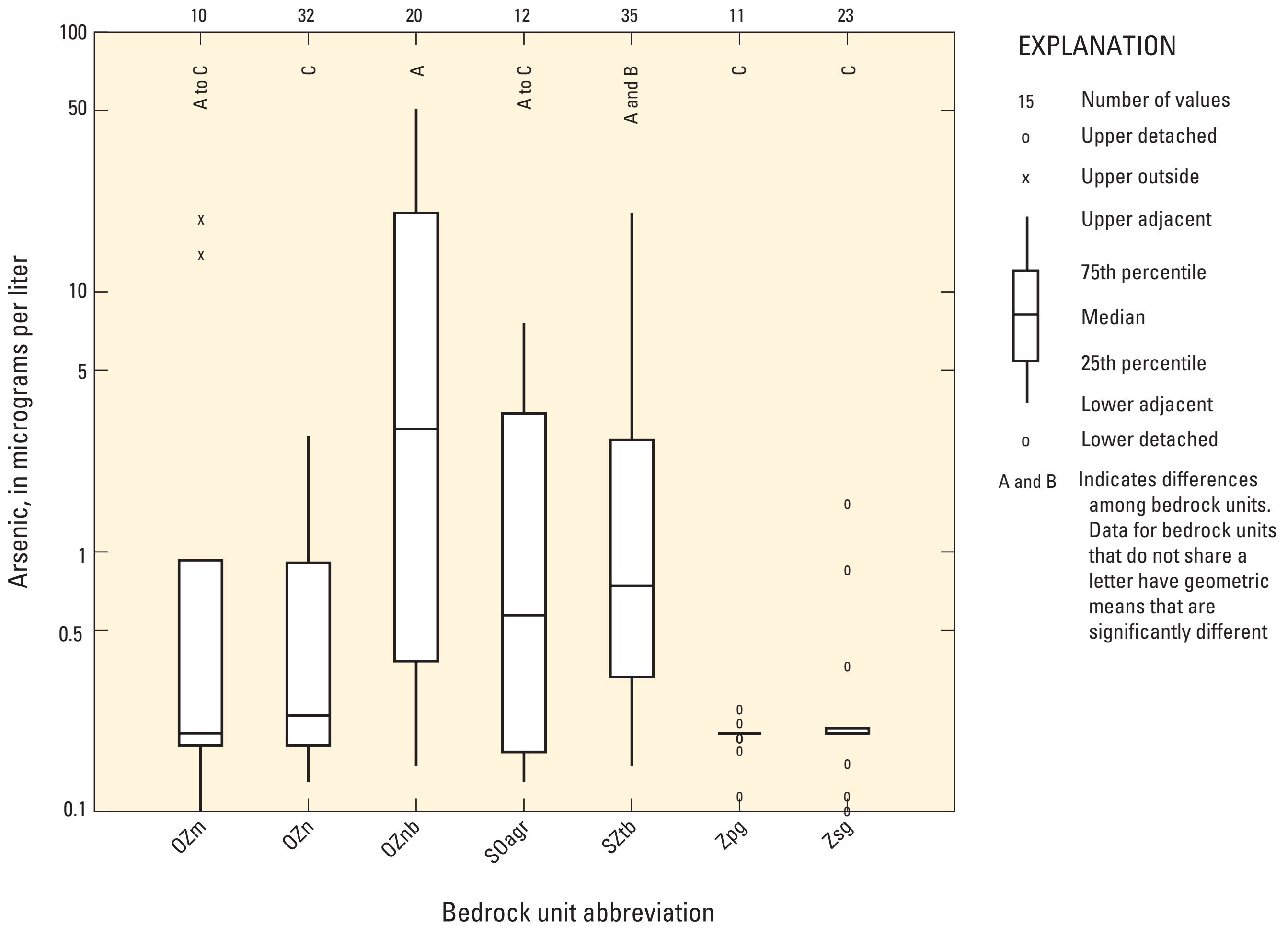
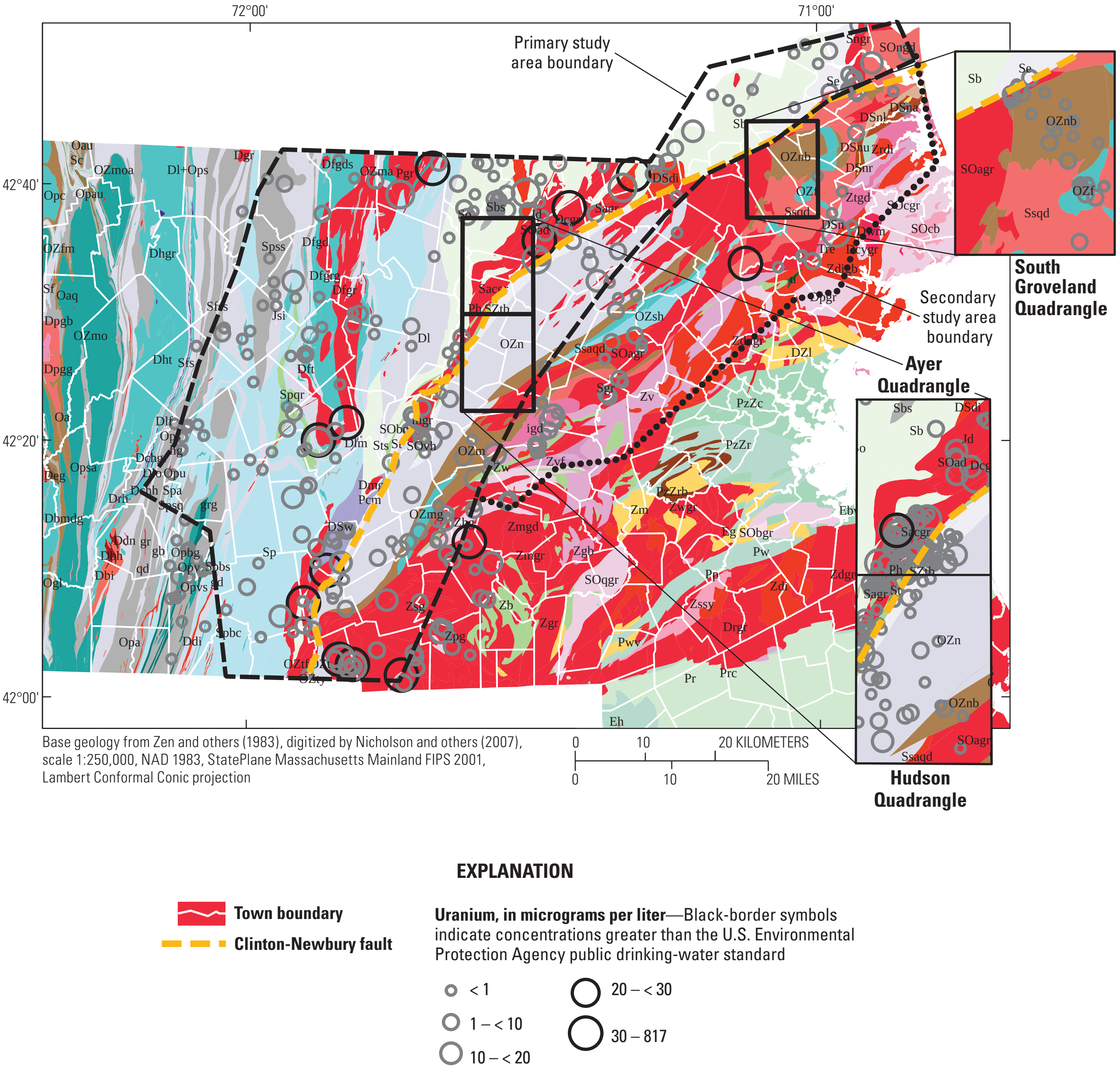


Figure 11. Distribution of arsenic concentrations by bedrock unit east of the Clinton-Newbury fault, east-central Massachusetts. See figure 3 and appendix 1 for explanation of bedrock units.



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

EXPLANATION

Town boundary

Clinton-Newbury fault

Uranium, in micrograms per liter—Black-border symbols indicate concentrations greater than the U.S. Environmental Protection Agency public drinking-water standard

○ < 1

○ 1 – < 10

○ 10 – < 20

○ 20 – < 30

○ 30 – 817

Figure 12. Uranium concentrations in east-central Massachusetts, 2009. Sampling coverage was increased in the areas of the insert maps where geology was mapped at the 1:24,000 scale. See figure 3 and appendix 1 for explanation of bedrock units. <, less than

Uranium Concentrations

Uranium concentrations ranged from less than the analytical reporting limit, 0.02 µg/L, to 817 µg/L. The low reporting limit allows description of uranium concentration variability in virtually all ranges of occurrence. Of 344 samples from the stratified random sampling, 12 samples (3.5 percent) exceeded the drinking-water standard of 30 µg/L. With the samples from the intensive sampling included, concentrations in 13 of the total of 478 samples (2.7 percent) were greater than the drinking-water standard. Elevated concentrations of uranium were widely distributed across the study area (fig. 12). As with arsenic, elevated uranium concentrations can be in close proximity to low concentrations in the same unit. Some units, however, had consistently low concentrations.

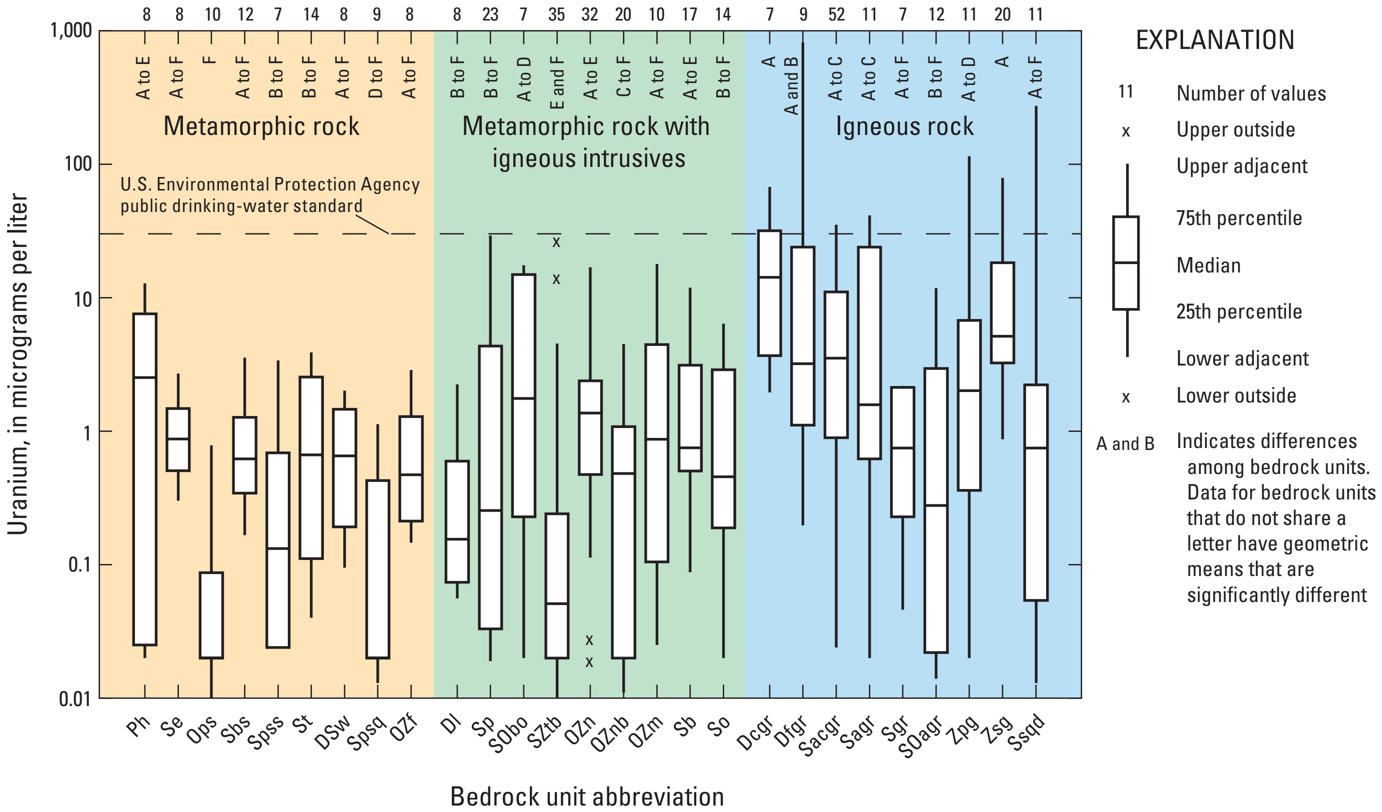


Figure 13. Distribution of uranium concentrations by bedrock unit, with seven or more samples, in the primary and secondary study area, east-central Massachusetts, 2009. See figure 3 and appendix 1 for explanation of bedrock units.

Uranium Correlations with Bedrock Units

Variation of uranium concentration by bedrock unit is apparent in units sampled seven or more times, a threshold used to increase statistical significance (fig. 13). Median concentrations are generally greater in igneous rock than in metamorphic rock (fig. 13). Concentrations in metamorphic rock intruded by igneous rock were intermediate. Concentrations were lowest in the unintruded metamorphic rock. Uranium concentrations exceeded the 30 µg/L drinking-water standard only in the igneous units.

The visual differences (fig. 13) were confirmed by one-way ANOVA analysis applied to the log-transformed uranium concentrations for bedrock units with seven or more samples, using rock type as a discrete independent variable. Significant differences were noted in concentrations among the rock types, indicating the association of rock type with distribution of uranium concentrations. Several bedrock units west of the Clinton-Newbury fault, such as Dcgr and Dl, were significantly different from each other.

Bedrock units classified as metamorphic, but intruded by igneous rocks, occasionally might be expected to reflect the elevated igneous concentrations. Well boreholes might intersect igneous rock even though the unit was classified as metamorphic, although this investigation did not find standard exceedences in metamorphic rock intruded by igneous rock. Intruded rock, however, did include concentrations that were greater than in unintruded rock.

Detailed Geologic Quadrangle Mapping of Bedrock Units

Several of the 1:24,000 quadrangles within the study area were remapped recently (three are shown in fig. 14). Some of the contacts between bedrock units are changed on the new maps compared to the State map (Zen and others, 1983; Nicholson and others, 2007). Bedrock unit identifications of some of the polygons also have changed. Correlations between arsenic and uranium concentration and the remapped units may be stronger than that of the State map if the newly identified units more accurately represent rock boundaries and if the concentrations are controlled by bedrock unit type.

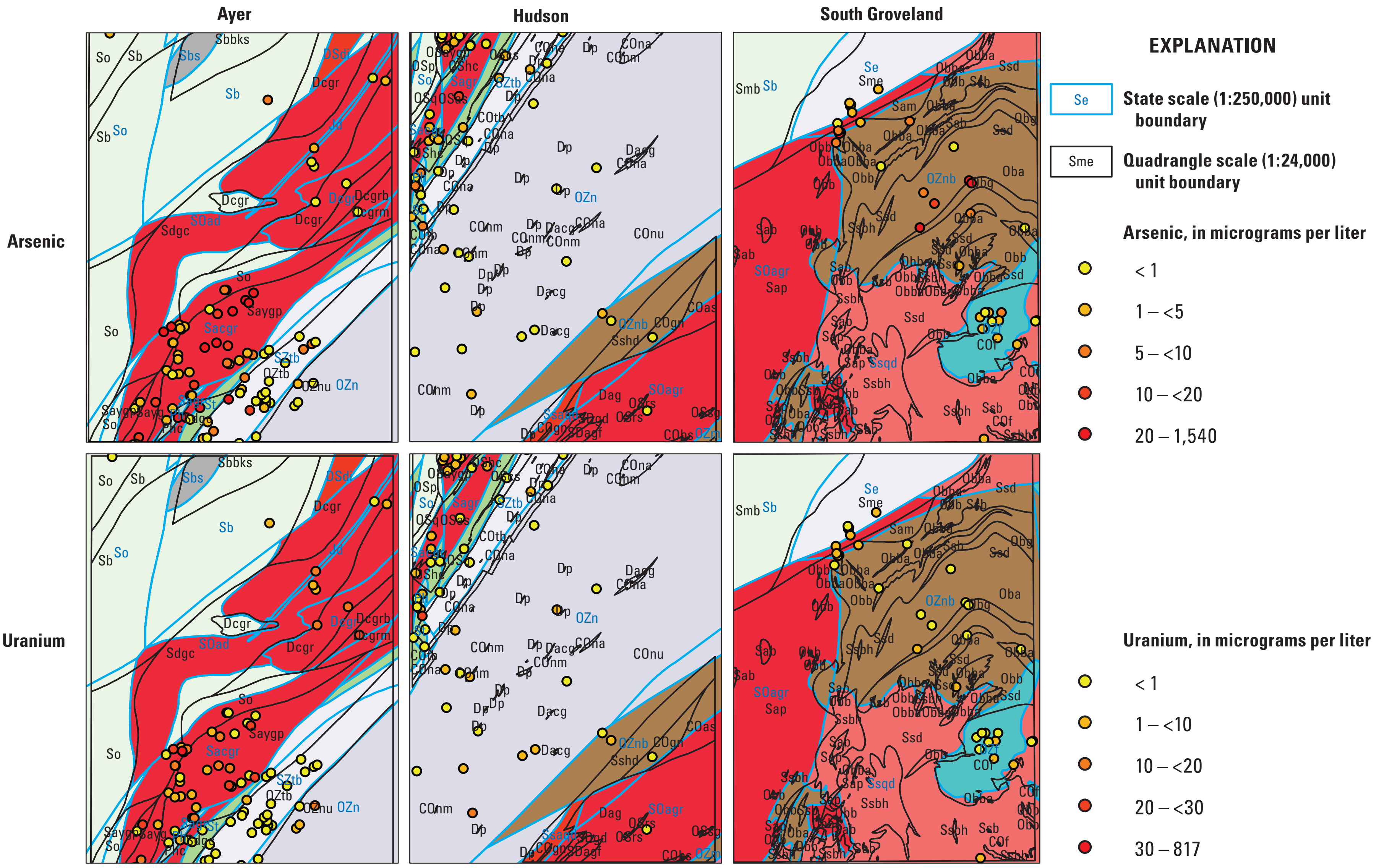


Figure 14. Details of change in geologic remapping of the Ayer, Hudson, and South Groveland 7.5-minute quadrangles compared to the statewide mapping of Zen and others (1983). <, less than

This effort reflects an attempt to test if the analysis of arsenic and uranium concentrations might be scale-dependent, as the 1:250,000 statewide map and 1:24,000 quadrangles differ significantly in scale. In New Hampshire, statewide analysis of well yield found that detailed (1:24,000) geologic maps improved the results of a predictive well-yield probability model over a statewide (1:250,000) model (Moore and others, 2002).

Correlations were compared by considering adjusted R-squared values for multiple linear regression of log concentration on bedrock unit for each pair of maps, that is, the map of Zen and others (1983) published in digital form by Nicholson and others (2007) compared to (1) the Ayer quadrangle (Kopera, 2006), (2) the Hudson quadrangle (Kopera, 2005) and (3) the South Groveland quadrangle (Castle and others, 2005) (table 3). Changes in renaming bedrock units alone would not change the value of the adjusted R-squared. Only a regrouping of well sites could change the R-squared value.

The adjusted R-squared value is a measure of the fraction of variance in the data that is explained by the regression variables. Results of the regressions indicate that no more variance of log-arsenic concentration is explained in the Ayer and Hudson quadrangles by the detailed (1:24,000) geologic mapping than by the statewide (1:250,000) mapping. For uranium, the adjusted R-squared value is about the same for the two mapping scales in the Ayer quadrangle but increases in the Hudson quadrangle with the 1:24,000 mapping. In the South Groveland quadrangle, more variance is explained with the new mapping than the old for both arsenic and uranium. One explanation for these results is the Clinton-Newbury fault that cuts though each quadrangle. In the Ayer and Hudson quadrangles, about half of the wells were in the elevated-arsenic zone where correlation with individual bedrock units was lacking. In the South Groveland quadrangle, only four wells were in the high arsenic zone, and all of these were in the same bedrock unit. Thus, arsenic would not improve with remapping for Ayer and Hudson because of a general lack of correlation by bedrock unit in much of the quadrangles. Uranium, by contrast, improved in two of the quadrangles with remapping and stayed about the same in the third. Overall, these results suggest that detailed mapping improves the ability to explain variance in uranium concentrations by bedrock unit, but that when variability in arsenic concentrations occurs at the terrane-scale, detailed mapping is less useful.

Table 3. Constituent correlation with bedrock units in statewide scale (1:250,000) and quadrangle scale (1:24,000), east-central Massachusetts.

[As, arsenic; U, uranium]

Geologic quadrangle	Regression	Adjusted R-squared	P value
Ayer	Log As, statewide scale	0.31	0.0001
Ayer	Log As, quadrangle scale	0.15	0.0198
Ayer	Log U, statewide scale	0.59	0.0000
Ayer	Log U, quadrangle scale	0.53	0.0000
Hudson	Log As, statewide scale	0.06	0.1952
Hudson	Log As, quadrangle scale	0.04	0.2997
Hudson	Log U, statewide scale	0.16	0.0225
Hudson	Log U, quadrangle scale	0.32	0.0010
South Groveland	Log As, statewide scale	0.03	0.3375
South Groveland	Log As, quadrangle scale	0.22	0.0578
South Groveland	Log U, statewide scale	0.05	0.2673
South Groveland	Log U, quadrangle scale	0.17	0.1006

Water-Quality Correlations with Ancillary Constituents

Analysis of ancillary constituents, acid neutralizing capacity, iron, manganese, and conductance was used to assess geochemical associations of arsenic and uranium occurrences. This was done using two-parameter plots (fig. 15). The plot matrix shows virtually no correlations among constituents. Some constituents appear to be mutually exclusive, particularly arsenic and iron, uranium and iron, and arsenic and uranium (fig. 15). This is in contrast to the relation found in overburden samples, where arsenic and iron are commonly correlated (Stollenwerk and Colman, 2003).

Peters (2008) attributes the difference in iron-arsenic association between overburden and bedrock as reflecting the lack of organic carbon likely present in bedrock units. Iron and arsenic associate in coatings deposited from oxic weathering of arsenic minerals, such as arsenopyrite. These coatings remain in place unless reducing conditions occur, such as associated with the presence of anthropogenic organic carbon (Stollenwerk and Colman, 2003; Peters, 2008). Iron concentrations were elevated in the water of some of the tested wells. The reducing conditions associated with these wells, however, were likely associated with sediments of wetlands or lakes that are providing recharge to the bedrock.

Bedrock Units, Geologic Terranes, and Geologic Sources of Arsenic and Uranium

The MDEP and the USGS data indicate that elevated arsenic in bedrock well water is associated primarily with two terranes in Massachusetts, the Merrimack belt and the Nashoba zone (figs. 1, 3, and 5). Within the terranes of elevated arsenic concentration, arsenic appeared to be correlated with bedrock

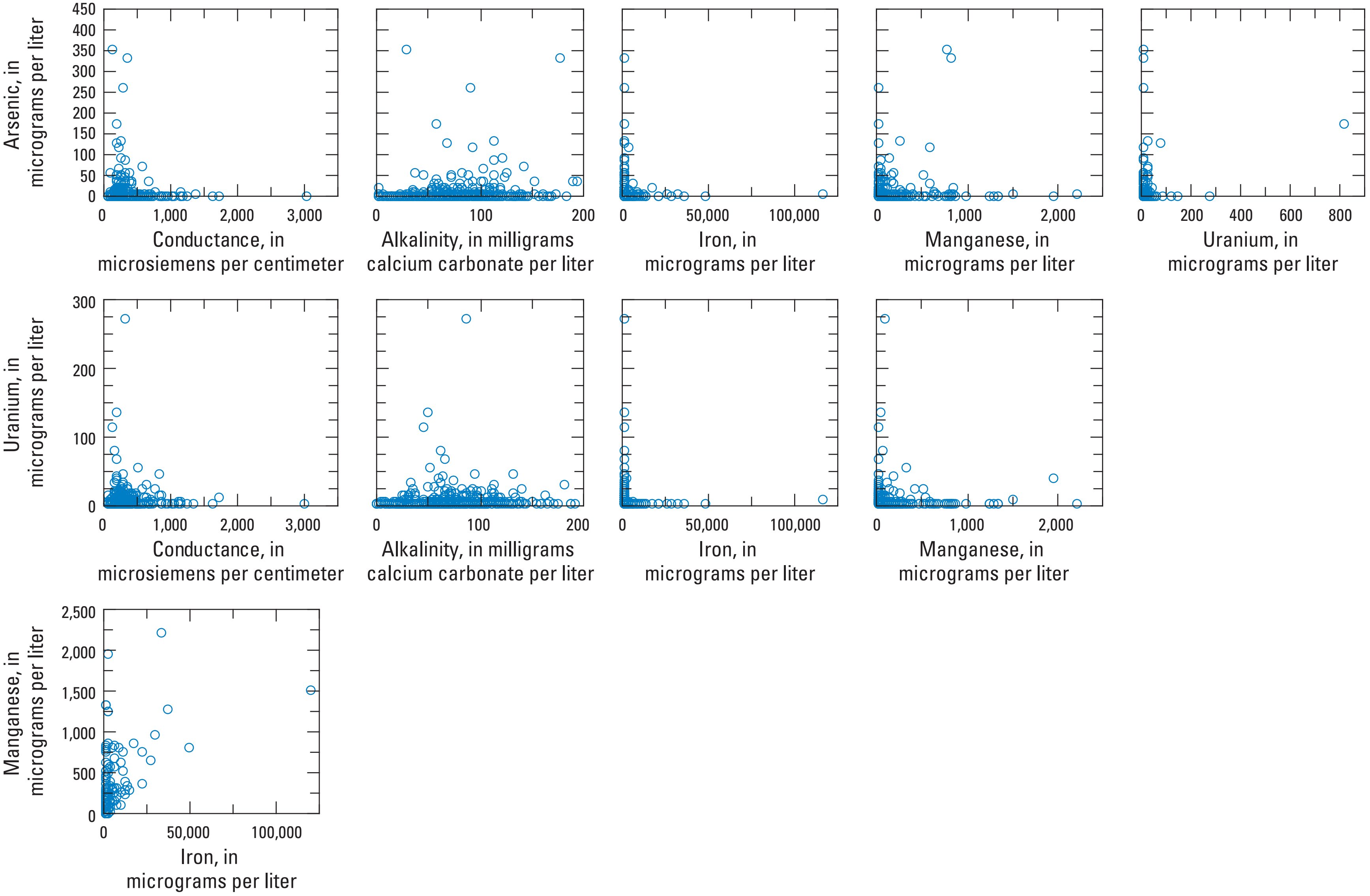


Figure 15. Associations among constituents measured in bedrock wells in east-central Massachusetts, 2009.

units in some parts of the study area and not correlated in other parts (note the elevated-concentration area of fig. 7). Sources of the arsenic in the areas that correlated with bedrock units could be in the rock protolith; however, the arsenic source in areas without bedrock correlation could have resulted from relatively equal redistribution of arsenic by metamorphic and/or metasomatic fluids from an original rock source (Henke, 2009). Although associated with the Merrimack belt, the elevated arsenic did not extend to the western border of the belt (fig. 9). The processes responsible for distributing the arsenic that is present in well water did not operate throughout the terrane.

In the Nashoba zone, where correlation between bedrock unit and arsenic concentrations was more prevalent, bedrock units with elevated arsenic extended to the Bloody Bluff fault, the eastern boundary of the zone. Two elevated arsenic concentrations were measured east of the Bloody Bluff fault in the Milford-Dedham zone, indicating that elevated arsenic concentrations are possible east of the Nashoba zone. Little previous data on arsenic in bedrock wells is available from this area where much of the water supply is public.

In the north, the elevated-arsenic area in Massachusetts abuts New Hampshire towns included in the private bedrock-well study by Montgomery and others (2003). In contrast to Massachusetts where units were grouped for concentration-probability analysis, units were grouped by fraction of samples greater than 10 µg/L in the New Hampshire study. The different statistical approaches prevent exact comparisons of data between the two States. Clearly, however, both States have elevated arsenic concentrations in the border area.

The association of igneous rock with uranium results from its deposition during magma cooling (Keevil and others, 1944). Uranium is one of the last elements to come out of solution, and it associates with rock surfaces from which mobilization into well water can occur. A report on uranium potential in two-mica granites of New England indicates that certain mineralized granites in New Hampshire and Massachusetts contain secondary uranyl-phosphate minerals (Boudette, 1977). Mobilization of uranium can occur in oxic conditions that are common in New England bedrock aquifers.

Maps of Estimated Probability for Elevated Arsenic and Uranium in Groundwater

Arsenic

Determination of probability of wells yielding water with arsenic concentration greater than the USEPA public drinking-water standard (10 µg/L) could help guide development of new supplies—domestic and public—and the testing of existing wells. Because of correlations of arsenic with bedrock unit and with groups of bedrock units described in a previous section on correlations, concentration distributions can be defined by bedrock unit. Cumulative distribution functions can be used to determine overstandard probabilities as well as probabilities of wells yielding water at levels of concentration greater than any given value (fig. 16). The distribution for each unit fits a log-normal distribution, and 95-percent confidence intervals based on the log-normal distribution can be computed (apps. 3 and 4).

The confidence interval of probability estimates depends on the number of samples for the bedrock unit and the concentration for which the probability is of interest. Probability distributions based on randomly selected samples of a population become more accurate as the sample size gets larger. Therefore, confidence intervals are a function of the number of samples. Finally, the probabilities can

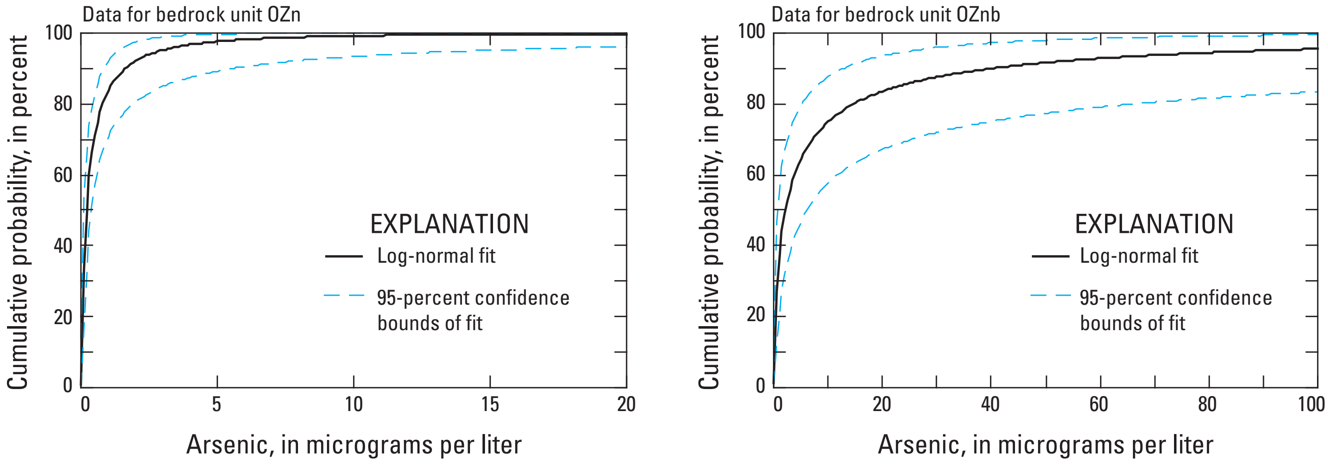
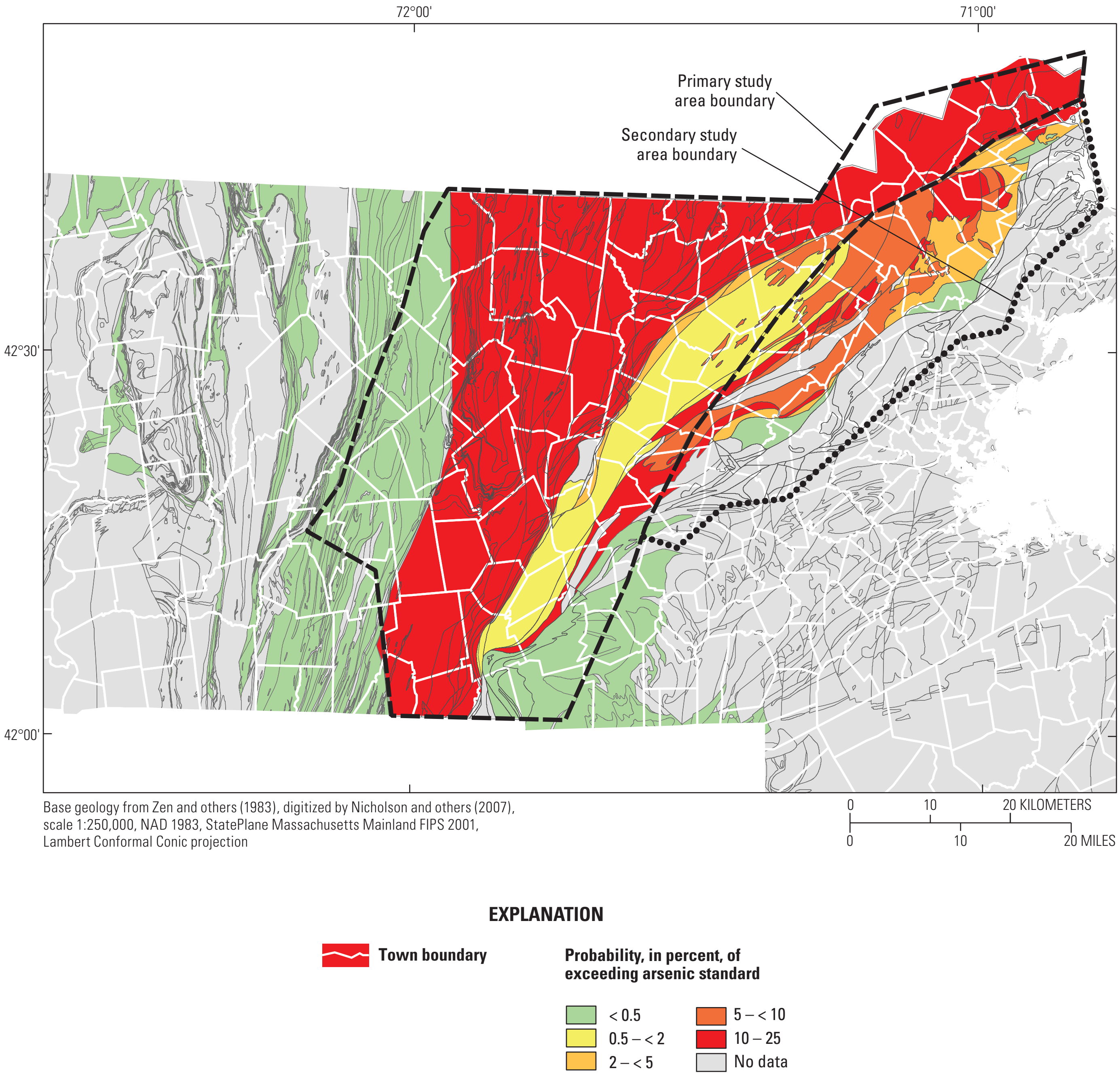


Figure 16. Cumulative probabilities for arsenic for two bedrock units east of the Clinton-Newbury fault.



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 17. Probabilities of arsenic concentrations in bedrock well water being greater than 10 micrograms per liter, the U.S. Environmental Protection Agency drinking-water standard for public supplies, east-central Massachusetts. <, less than

be mapped so that areas with higher or lower probabilities of concentration than a given level (such as the USEPA drinking-water standard for public water supply) can be known (fig. 17). For example, the probability that a well in the OZn bedrock unit will contain water with an arsenic concentration greater than 10 µg/L (equal to 100 percent minus the cumulative probabililty) is low—0.79 percent with 95-percent confidence interval of 0.05 to 6.6 percent (fig. 16 and app. 3). The probability that a well will contain water with arsenic concentration greater than 10 µg/L for OZnb, an elevated-concentration unit, is 26 percent with a 95-percent confidence interval of 13 to 43 percent.

Bedrock units in the elevated-concentration area (fig. 7) were grouped for computing cumulative probabilities. The probability of well water being greater than 10 µg/L for the elevated-concentration grouping of units was 23 percent, exceeded only by OZnb at 25 percent.

Uranium

In this study, uranium is more generally correlated to bedrock unit than is arsenic, so uranium associations can be mapped exclusively by bedrock unit. Distributions of uranium concentration in a bedrock unit are log normal. Cumulative log-normal distributions indicate the probability of concentrations occurring for the whole range of concentrations, including the probability of exceeding 30 µg/L, the USEPA drinking-water standard for public supplies. The 95-percent confidence intervals of the probability estimates can also be determined from the log-normal fits (fig. 18, apps. 5 and 6). The uncertainty of the predictions—that is, the size of the confidence interval—decreases at high and low ends of the concentration range (fig. 18).

Example probabilities of encountering a concentration greater than 30 µg/L (fig. 18) range from 0.0001 percent (95-percent confidence interval of 0.0 to 0.005 percent) for Ops, to 21 percent (95-percent confidence interval of 5.5 to 50 percent) for Dcgr. Areas with granitic rock have higher probabilities (figs. 5 and 19).

Estimates of the Number of Wells that Exceed USEPA Drinking-Water Standards

Estimates of the number of wells affected can be determined by the product of the probability for well water to exceed the USEPA standard and the estimated number of wells per bedrock unit.

Estimates of private well distributions were made for the MDPH by Weston & Sampson Engineers, Inc., during 2005 (fig. 20). Potential private wells were identified by cross-referencing addresses in property-tax-assessment databases

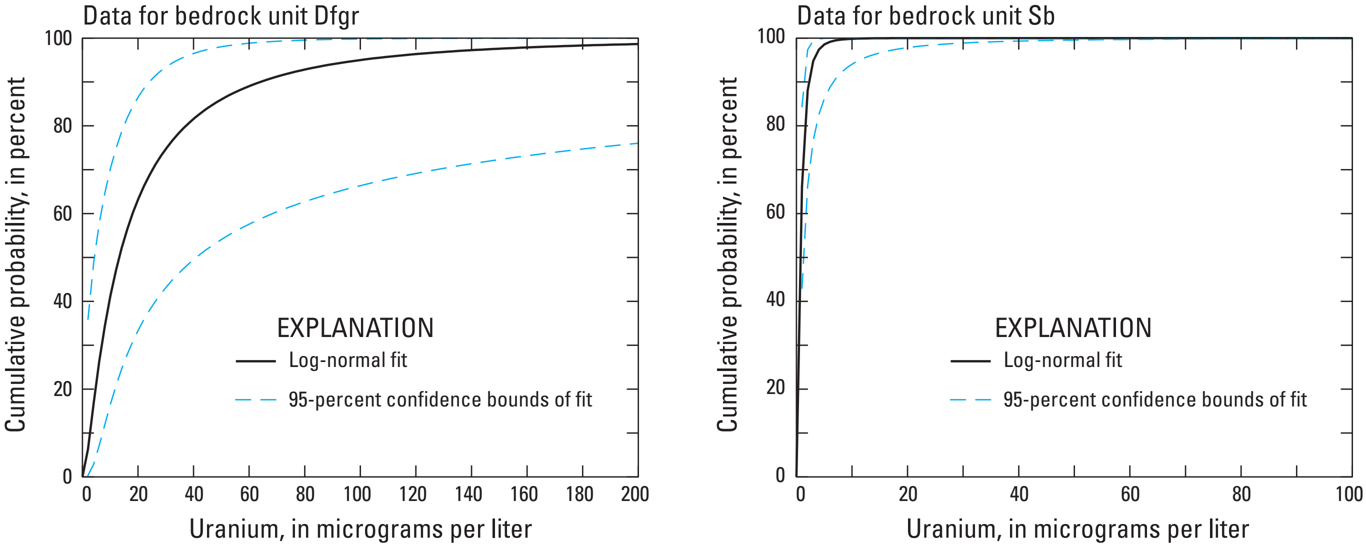
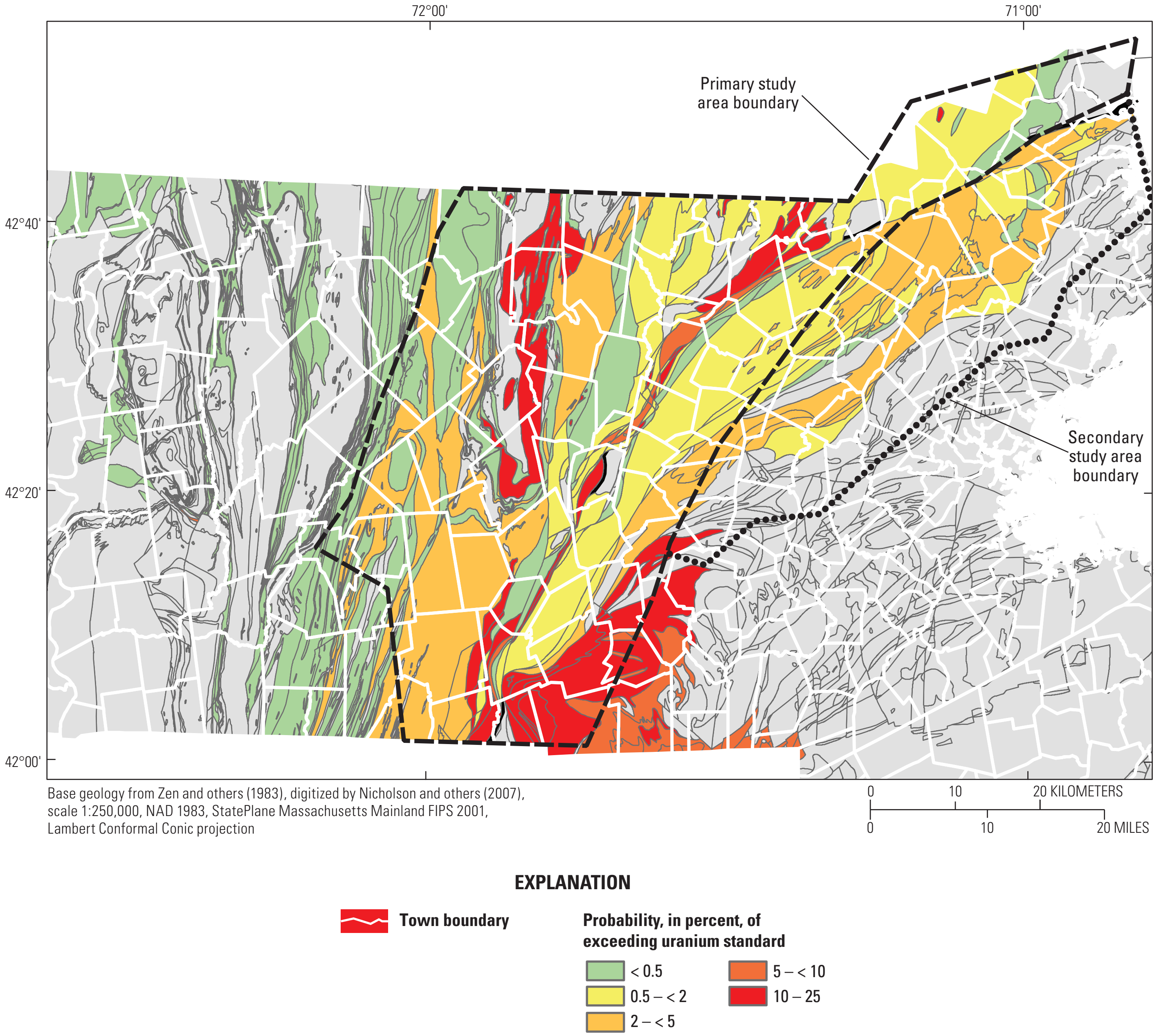


Figure 18. Cumulative log-normal distribution functions for uranium in an elevated-concentration bedrock unit, Dfgr, and a low-concentration bedrock unit, Sb, east-central Massachusetts.

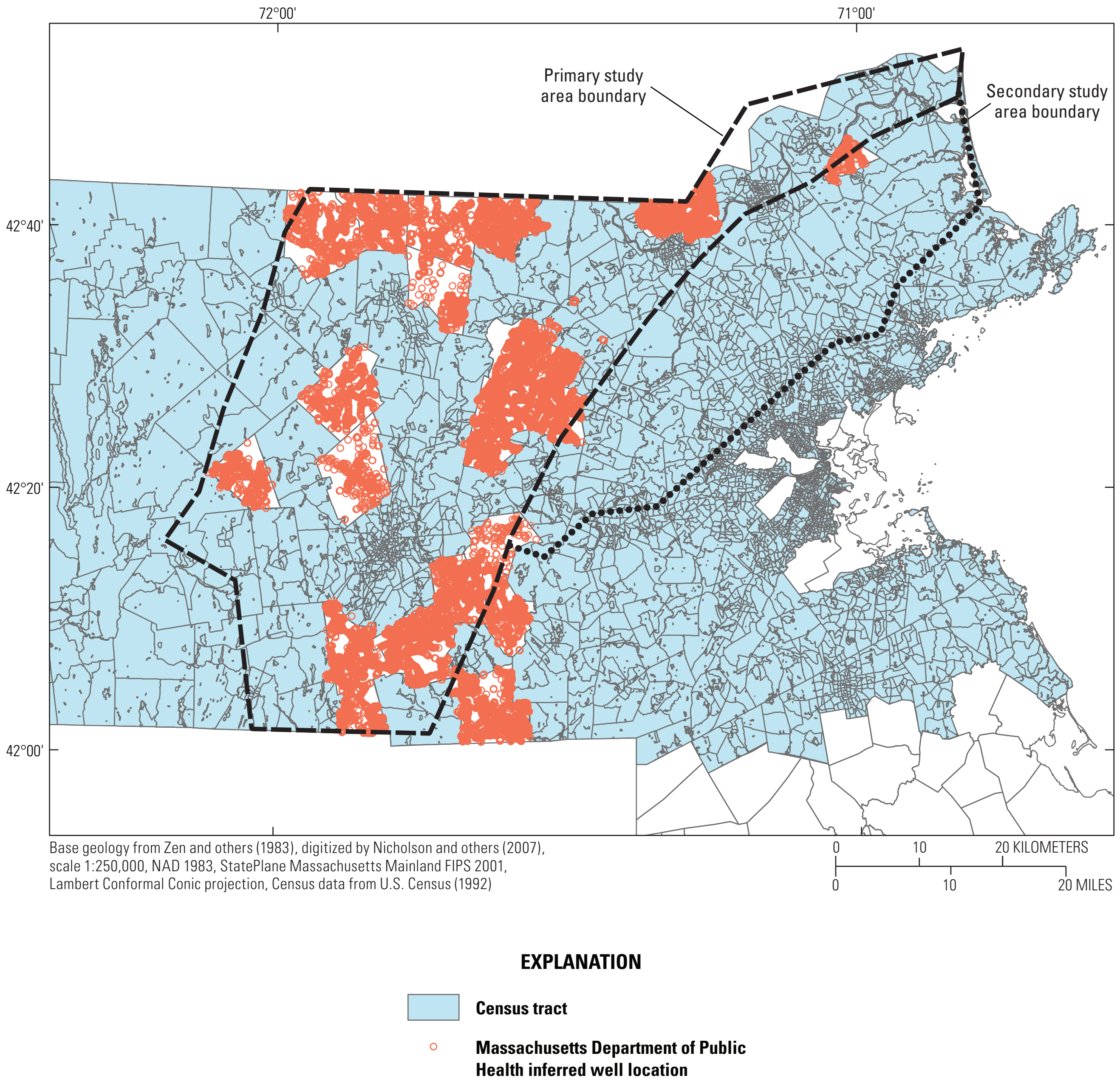


Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection

Figure 19. Probabilities of uranium concentrations in bedrock well water being greater than 30 micrograms per liter, the U.S. Environmental Protection Agency drinking water standard for public supplies, east-central Massachusetts. <, less than

with those in water-billing databases. The addresses in the tax-assessment databases that did not have a match in the water-billing databases were classified as potential private wells. In communities not served by a public water supply, all addresses contained in the tax-assessment data were classified as potential private wells. For the purposes of the estimate, all the inferred private wells were assumed to be bedrock wells. All the potential private well addresses were geocoded using the GDT/TeleAtlas Batch Geocoding Service®.

Not all towns in the study area were included in the MDPH inferred private-well investigation (fig. 20). The 1990 census, which provided information about households per census track and percentage of households on public or private water, was used to supplement well estimates in locations not covered by MDPH (U.S. Census, 1992). The census areas in towns not covered by the MDPH study were intersected with the bedrock data using Geographic Information System (GIS) techniques to delineate parts of census tracts that were in each



Base geology from Zen and others (1983), digitized by Nicholson and others (2007), scale 1:250,000, NAD 1983, StatePlane Massachusetts Mainland FIPS 2001, Lambert Conformal Conic projection, Census data from U.S. Census (1992)

Figure 20. Inferred locations of private wells and census tracts for towns not included in the inferred private-well study, east-central Massachusetts.

Table 4. Number of wells in each bedrock unit and estimates of number of wells exceeding the arsenic and uranium U.S. Environmental Protection Agency drinking-water standards for public supplies, east-central Massachusetts.

[* , bedrock unit within the high-arsenic zone; —, no data; MDPH, Massachusetts Department of Public Health; µg/L, micrograms per liter; standard, U.S.Environmental Protection Agency public drinking-water standard]

Bedrock unit	Total number of MDPH wells	Total number of estimated census wells	Probability of arsenic concentrations greater than 10 µg/L, in percent	Probability of uranium concentrations greater than 30 µg/L, in percent	Estimated number of wells exceeding the 10 µg/L standard for arsenic	Estimated number of wells exceeding the 30 µg/L standard for uranium
Grouped elevated-arsenic units	13,500	5,763	23.08	—	4,445	—
Dcgr*	418	1,275	—	21.01	—	356
Dfgr*	1,522	702	—	13.97	—	311
Dl	2,010	8,024	0.00	0.03	0	3
DSw*	382	629	—	0.13	—	1
Ops	770	7,707	0.10	0.00	8	0
OZf	0	507	7.64	0.01	39	0
OZm	735	679	10.83	4.64	153	66
OZn	7,007	5,621	0.79	0.89	100	113
OZnb	930	1,357	25.50	0.70	583	16
Ph*	60	0	—	11.99	—	7
Sacgr*	884	373	—	8.43	—	106
Sagr*	971	1,013	—	12.54	—	249
Sb*	2,315	4,594	—	0.69	—	47
Sbs*	67	133	—	0.00	—	0
Se*	305	492	—	0.00	—	0
Sgr	0	533	0.00	0.64	0	3
So*	1,374	2,406	—	1.55	—	59
SOagr	569	2,326	6.92	4.11	200	119
SObo*	0	236	—	12.42	—	29
Sp	2,862	10,343	0.00	4.61	0	609
Spsq	85	238	0.14	0.07	0	0
Spss	908	723	0.38	0.18	6	3
Ssqd	224	2,982	4.63	2.53	148	81
St*	245	150	—	0.76	—	3
SZtb	861	464	3.68	0.17	49	2
Zpg	2,197	1,361	0.02	6.94	1	247
Zsg	5,012	2,972	0.10	10.61	8	847
Totals	**32,713**	**57,840**			**5,741**	**3,277**

bedrock unit. The number of wells per census tract was then adjusted by the proportional area of the tract that was in the bedrock unit. Finally, all the wells in the parts of tracts in a bedrock unit were added to determine the number of wells in each unit. The number of wells estimated to exceed a standard was determined by multiplying the probability of exceeding a standard for that bedrock unit by the sum of the number of wells determined from the MDPH assessment and the census assessment (table 4).

Arsenic

For arsenic, no probability was given in table 4 for bedrock units that were within the elevated-arsenic area. Rather, the probabilities for the units in this area are covered by the grouped-units estimate (top of table 4).

The number of wells with arsenic concentrations that exceeded the USEPA drinking-water standard was estimated to be 5,741. Because the study area covered most of the known elevated-concentration areas for the State, this estimate is likely appropriate for the entire State. Several small units within the study area did not have enough data for probability statistics to be computed; however, these would not greatly alter the total.

Uranium

For uranium, correlations were strictly with bedrock units rather than grouped units (table 4). The number of wells with uranium concentrations that exceeded the standard for uranium was estimated to be 3,277. Most of these wells are in igneous rock. Because units west of the Clinton-Newbury fault were not grouped on an areal basis for uranium, several more bedrock units were excluded from the calculation of probability statistics than for arsenic.

Igneous bedrock units in Massachusetts are not confined to the primary and secondary study areas of this investigation. The statewide number of wells affected by uranium is likely larger than the number reported herein, based on the bedrock units in the study areas.

Implications for New Supplies, Testing, and Treatment

Locating Future Bedrock Water Supplies

Few private well owners have options regarding choosing locations that have favorable bedrock. For private supply, the probability maps (figs. 17 and 19) can be used to guide well-water testing.

Although the data collected were from private wells, the data could be used to assess conditions likely in public as well as private bedrock water supplies. Commonly, there are several site options for locating public wells. Consideration of the bedrock unit when selecting sites for public supplies could result in substantially decreased probabilities of concentrations exceeding the drinking-water standard. Towns that straddle the Clinton-Newbury fault, such as Harvard and Westford, could make use of the result that there is a lower probability of elevated arsenic concentration in the rocks east of the fault than those to the west.

Directing Resources for Water Testing

The numbers of overstandard water supplies without treatment can be computed by using the fraction of households currently using water without treatment for arsenic (66 percent of 5,741 = 3,789) and uranium (93 percent of 3,277 = 3,047). If testing could be directed toward the elevated-concentration areas, these numbers of untreated supplies would presumably decrease. By testing all wells that are in bedrock units with probabilities of elevated arsenic concentration greater than 10 percent, 90 percent of the wells exceeding the standard could be identified. Applied to data collected in this investigation, for example, all but two wells exceeding the standard (which are in SZtb with concentrations of 10 and 20 μg/L) would have been tested. This approach is likely to include testing of the highest concentration wells, because the elevated concentrations are associated with bedrock units that have the highest probabilities of overstandard concentrations. For example, of the two wells that were missed by this approach, one had a concentration at the standard and one had a concentration twice the standard; the highest concentration well tested in this study had a concentration 150 times the standard.

Because health risk increases with increasing concentration, a testing routine that likely includes the highest concentrations is beneficial. The 10-percent probability testing algorithm would result in testing 26 percent of all the wells estimated to be in the study areas. As a fraction of wells statewide, the percentage of wells tested would, of course, be much smaller.

For uranium, to determine 90 percent of wells greater than the standard, all units with overstandard probability of 4 percent or greater would need to be analyzed. This would involve testing about 40 percent of the wells in the study area.

Defining Natural Background Concentrations

A problem for site-contamination assessment in areas where arsenic occurs naturally is whether concentrations at a given site are caused by natural conditions or are the result of human-induced activity. In cases where there is a possibility that the bedrock has been contaminated with anthropogenic arsenic, the distribution frequencies of concentration for a given bedrock unit could be used to assess whether or not the distribution frequency of concentration at a site that is suspected of contamination is significantly different from natural conditions.

Summary

This investigation is the first regional-scale study of arsenic concentrations in water from private wells completed in bedrock throughout east-central Massachusetts, the region of elevated-arsenic concentrations in the State. Measurements of uranium concentrations also were included in the investigation, because uranium, similar to arsenic, likely has a bedrock source. Although private water supplies are not subject to new U.S. Environmental Protection Agency (USEPA) drinking-water standards for public-water supplies, such as those established for arsenic and uranium in the last 7 years of 10 and 30 micrograms per liter, respectively, the standards are thresholds whereby private well users can assess the need for water treatment. Concentration data are needed for arsenic and uranium concentrations to (1) assess the geographic distribution of elevated concentrations, (2) guide testing of existing supplies, and (3) develop new supplies. These needs were addressed by correlating concentrations of arsenic and uranium with bedrock units and applying the correlations to the mapped distributions of wells. For arsenic, the number of overstandard wells estimated by these methods in the study area would account for most of the overstandard wells in the State. For uranium, the number of overstandard wells estimated for the study area would be less than the total for the State, because bedrock units with elevated concentrations of uranium are also expected outside of the region of this study.

Samples were collected by private well users that responded to sampling kits that were mailed to randomly selected well addresses. An instruction sheet and water-use questionnaire were included in the sampling kit. Of the wells randomly sampled, 13 percent had concentrations that exceeded the drinking-water standard for arsenic, and 3.5 percent exceeded the drinking-water standard for uranium.

One-way ANOVA analysis of log-transformed concentration data indicated significant differences for arsenic and for uranium concentration populations grouped by bedrock unit in most of the study area. However, an area of elevated arsenic concentrations was identified west of the Clinton-Newbury fault, where there were no significant differences in arsenic concentrations among the bedrock units. Lack of correlation with individual bedrock units in this area could have resulted from relatively equal redistribution of arsenic by metamorphic and/or metasomatic fluids.

Concentrations of arsenic and uranium fit log-normal distributions for populations separated by bedrock unit. For each bedrock unit, log-normal fits of the data were used to determine probabilities of concentrations exceeding the drinking-water standards. Overstandard probabilities were as great as 26 percent for arsenic in a unit containing amphibolite and 21 percent for uranium in a granitic unit.

Water-use data from the well users indicated that most of the overstandard wells were being used for drinking water without treatment—66 percent for arsenic and 93 percent for uranium. This data together with probability and well-distribution data were used to estimate the potential total number of wells in the study area used for drinking water without treatment: approximately 3,800 for arsenic and 3,000 for uranium.

Probability and well-distribution data were also used to determine the sampling effort required to locate 90 percent of the estimated overstandard wells. For arsenic, this could be achieved by sampling wells in those bedrock units with an overstandard probability of 10 percent or greater. This would involve sampling 26 percent of the total number of wells in the study area. For uranium, 90 percent of overstandard wells could be determined by sampling wells in bedrock units with an overstandard probability of 4 percent or greater. This would involve sampling 40 percent of all the wells in the study area.

Increased sampling in the investigation was directed in the regions of three 1:24,000 quadrangles where recent detailed geologic mapping had been conducted. Improved correlations of arsenic and uranium with bedrock unit were measured for two of the three quadrangles compared to the correlations made with the statewide map.

The correlations with bedrock are compatible with a natural bedrock source of the contaminants. By addressing the potential for contamination of bedrock wells in areas of increased contamination probability, well owners and resource managers can better assess risk.

References Cited

Ayotte, J.D., Flanagan, S.M., and Morrow, W.S., 2007, Occurrence of uranium and ^{222}radon in glacial and bedrock aquifers in the northern United States, 1993–2003: U.S. Geological Survey Scientific Investigations Report 2007–5037, 84 p.

Ayotte, J.D., Montgomery, D.L., Flanagan, S.M., and Robinson, K.W., 2003, Arsenic in groundwater in eastern New England—Occurrence, controls, and human health implications: Environmental Science and Technology, v. 37, p. 2075–2083.

Ayotte, J.D., Nolan, B.T., Nuckols, J.J., Cantor, K.P., Robinson, G.R., Baris, D., Hayes, L., Karagas, M., Bress, W., Silerman, D.T., and Lubin, J.H., 2006, Modeling the probability of arsenic in groundwater in New England as a tool for exposure assessment: Environmental Science and Technology, v. 40, p. 3,578–3,585.

Boudette, E.L., 1977, Two-mica granite and uranium potential in the northern Appalachian orogen of New England, *in* Campbell, J.A., ed., Short papers of the U.S. Geological Survey uranium-thorium symposium: U.S. Geological Survey Circular 753, p. 23–24.

Boudette, E.L., Canney, F.C., Cotton, J.E., Davis, R.I., Ficklin, W.H., and Motooka, J.M., 1985, High levels of arsenic in the groundwater of southeastern New Hampshire—A geochemical reconnaissance: U.S. Geological Survey Open-File Report 85–202, 20 p.

Castle, R.O., Hepburn, J.C., and Kopera, J.P., 2005, Bedrock geologic map of the South Groveland Quandrangle, Massachusetts: Office of the Massachusetts State Geologist, University of Massachusetts, 1 sheet.

Centeno, J.A., Tseng, C.-H., Van der Voet, G.B., and Finkelman, R.B., 2007, Global impacts of geogenic arsenic—A medical geology research case: Ambio, v. 36, no. 1, p. 78–81.

DeSimone, L.A., 2009, Quality of water from domestic wells in principal aquifers of the United States, 1991–2004: U.S. Geological Survey Scientific Investigations Report 2008–5227, 139 p., available online at *http://pubs.usgs.gov/sir/2008/5227*

Devesa, S.S., Grauman, D.G., Blot, W.J., Pennello, G., Hoover, R.N., Fraumeni, J.F., Jr., 1999, Atlas of cancer mortality in the United States, 1950–94: Washington, D.C., National Institutes of Health Publication no. 99–4564: U.S. Government Printing Office.

Garbarino, J.R., Kanagy, L.K., and Cree, M.E., 2006, Determination of elements in natural-water, biota, sediment and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, sec. B, chap. 1, 88 p.

Garbarino, J.R., and Struzeski, T.M., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of elements in whole-water digests using inductively coupled plasma-optical emission spectrometry and inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 98–165, 101 p.

Hansen, B., and Simcox, A.C., 1994, Yields of bedrock wells in Massachusetts: U.S. Geological Survey Water-Resources Investigations Report, 93–4115, 43 p.

Hatch, N.L., ed., 1991, The bedrock geology of Massachusetts: U.S. Geological Survey Professional Paper 1366–E–J [variously paged].

Henke, Kevin, 2009, Arsenic in natural environments, *in* Henke, Kevin, ed., Arsenic—Environmental chemistry, health threats and waste treatment: Hoboken, Wiley, p. 69–236.

Iman, R.L., and Conover, W.J., 1983, A modern approach to statistics: New York, Wiley, 497 p.

Karagas, M.R., Stukel, T.A., and Tosteson, T.D., 2002, Assessment of cancer risk and environmental levels of arsenic in New Hampshire: International Journal of Hygiene and Environmental Health, v. 205, p. 85–94.

Keevil, N.B., Larsen, E.S., Jr., and Wank, F.J., 1944, The Ayer granite-migmatite at Chelmsford, Massachusetts, pt. 6 *of* The distribution of helium and radioactivity in rocks: American Journal of Science, v. 242, no. 7, p. 345–353.

Kopera, J.P., 2005, Preliminary bedrock geological map of the Hudson quandrangle, Massachusetts: Office of the Massachusetts State Geologist, University of Massachusetts, Massachusetts Geologic Survey, 1 sheet.

Kopera, J.P., 2006, Preliminary bedrock geologic map of the Ayer quadrangle, Massachusetts: Office of the Massachusetts State Geologist Open File Report 06–02, 1 sheet.

Lamm, S.H., Byrd, D.M., Kruse, M.B., Feinleib, M., Lai, S-H., 2003, Bladder cancer and arsenic exposure—Differences in the two populations enrolled in a study in southwest Taiwan: Biomedical and Environmental Sciences v. 16, p. 355–368.

Leggett, R.W., 1989, The behavior and chemical toxicity of U in the kidney—A reassessment: Health Physics, v. 57, no. 3, p. 365–383.

Lyford, F.P., Carlson, C.S., and Hansen, B.P., 2003, Delineation of water sources for public-supply wells in three fractured-bedrock aquifer systems in Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 02–4290, 114 p.

Marvinney, R.G., Loiselle, M.C., Hopeck, J.T., Braley, David, and Krueger, J.A., 1994, Arsenic in Maine ground water—An example from Buxton, Maine, *in* Proceedings of the 1994 FOCUS conference on Eastern Regional Ground Water Issues, Burlington, Vt.: National Ground Water Association, p. 701–715.

Massachusetts Department of Environmental Protection, 2008, Parameters and testing frequency for private wells: Commonwealth of Massachusetts, accessed October 2010 at *http://www.mass.gov/dep/water/drinking/privatew.htm*

Massachusetts Office of Geographic Information (MassGIS), 2005, Othophoto quads index: Commonwealth of Massachusetts, accessed June 2007 at *http://www.mass.gov/mgis/ix_oq.htm*

Montgomery, D.L., Ayotte, J.D., Carroll, P.R., and Hamlin, P., 2003, Arsenic concentrations in private bedrock wells in southeastern New Hampshire: U.S. Geological Survey Fact Sheet 051–03, 6 p.

Moore, R.B., Schwarz, G.E., Clark, S.F. Jr., Walsh, G.J., and Degnan, J.R., 2002, Factors related to well yield in the fractured-bedrock aquifer of New Hampshire: U.S. Geological Survey Professional Paper 1660, 36 p.

Moyer, L.A., Hastings, J.T., and Raines, G.L., 2005, Methods to create ArcMap® styles with examples for lithology and time: U.S. Geological Survey Open-File Report 2005–1314, 21 p.

National Research Council, 2001, Arsenic in drinking water—2001 update: Washington, D.C., National Academy Press, 244 p.

Nicholson, S.W., Dicken, C.L., Horton, J.D., Foose, M.P., Mueller, J.A.L., and Hon, Rudi, 2007, Preliminary integrated geologic map databases for the United States—Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, Rhode Island, and Vermont: U.S. Geological Survey Open-File Report 2006–1272, version 1.1, accessed at *http://pubs.usgs.gov/of/2006/1272/*

Peters, S.C., 2008, Arsenic in groundwaters in the northern Appalachian mountain belt—A review of patterns and processes: Journal of Contaminant Hydrology, v. 99, p. 8–21.

Pierce, H.A., Walsh, G.J., Burruss, R.C., and Degnan, J.R., 2007, Borehole characterization of a methane-yielding bedrock well, Tyngsborough, Massachusetts: U.S. Geological Survey Open-File Report 2007–1399, 17 p., accessed at *http://pubs.usgs.gov/of/2007/1399/*

Radtke, D.B., Davis, J.V., and Wilde, F.D., 2005, Specific electrical conductance (ver. 1.2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, section 6.3, August, accessed June 2009 at *http://pubs.water.usgs.gov/twri9A6/*

Ritz, G.F., and Collins, J.A., 2008, pH (version 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, sec. 6.4, October, accessed May 2009 at *http://pubs.water.usgs.gov/twri9A6/*

Rounds, S.A., 2006, Alkalinity and acid neutralizing capacity (ver. 3.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6, sec. 6.6, July, accessed June 2009, at *http://pubs.water.usgs.gov/twri9A6/*

SEA Consultants, 1985, Investigation of arsenic contamination in private wells, Pepperell, Massachusetts: Cambridge, Mass. [variously paged].

Smith, A.H., Hopenhayn-Rich, C., Bates, M.N., Goeden, H.M., Hertz-Picciotto, I., Duggan, H.M., Wood, R., Kosnett, M.J., and Smith, M.T., 1992, Cancer risks from arsenic in drinking water: Environmental Health Perspectives, v. 97, p. 259–267.

Stollenwerk, K.G., and Colman, J.A., 2003, Natural remediation potential of arsenic contaminated ground water, *in* Welch, A.H., and Stollenwerk, K.G., eds., Arsenic in ground water—Geochemistry and occurrence: Boston, Kluwer, p. 351–380.

Taylor, D.M., and Taylor, S.K., 1997, Environmental uranium and human health: Reviews on Environmental Health, v. 12, no. 3, p. 147–157.

U.S. Census, 1992, 1992 U.S. Census enhanced TIGER/Line files for the fourteen counties of Massachusetts: Accessed May 2009 at *http://www.mass.gov/mgis/cen1990_block-groups.htm*

Zen, E-An (ed.), Goldsmith, R., Ratcliffe, N.M., Robinson, P., Stanley, R.S. (compilers), Hatch, N.L., Jr., Shride, A.F., Weed, E.G.A., and Wones, D.R., 1983, Bedrock geologic map of Massachusetts: Reston, Va., U.S. Geological Survey, scale 1:250,000, 3 sheets.

Zuena, A.J., and Keane, N.W., 1985, Arsenic contamination in private potable wells, *in* USEPA National Conference on Environmental Engineering, Northeastern University of Boston, Massachusetts, p. 717–725.

Appendix 1. Abbreviations and Descriptions for Bedrock Units in and Adjacent to the Study Area

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area.

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
Cbw	Cambrian	Braintree Argillite and Weymouth Fm—argillite, with some rare limestone
Cg	Cambrian	Green Lodge Fm of Rhodes and Graves (1931)—quartzite and slate
Ch	Cambrian	Hoppin Fm—quartzite, argillite, and minor limestone
cu	Unknown age	Cumberlandite—rock containing magnetite, ilmenite, olivine, labradorite, and spinel
Dcgr	Devonian	Chelmsford Granite—muscovite-biotite granite
Dchgr	Devonian	Coys Hill Porphyritic Granite Gneiss—microcline granite gneiss
Dchh	Devonian	Coys Hill Porphyritic Granite Gneiss— hornblende gneiss inclusions
Dcygr	Devonian	Cherry Hill Granite—alaskite granite containing ferro-hornblende
Ddi	Devonian	Hardwick Tonalite: Biotite-hornblende diorite and quartz-bearing diorite
Ddn	Devonian	Hardwick Tonalite: Meladiorite and norite
Dfgd	Devonian	Fitchburg Complex—biotite granodiorite to tonalite gneiss
Dfgds	Devonian	Fitchburg Complex—biotite-muscovite granitic gneiss with mica schist and feldspathic granulite inclusions
Dfgr	Devonian	Fitchburg Complex—muscovite-biotite granite
Dfgrg	Devonian	Fitchburg Complex—biotite-muscovite granite to granodiorite gneiss
Dft	Devonian	Fitchburg Complex—biotite-hornblende tonalite inclusions
Dgd	Devonian	Granodiorite
Dgr	Devonian	Biotite-muscovite granite
Dhgr	Devonian	Hardwick Tonalite—porhyritic microcline-biotite granite gneiss
Dht	Devonian	Hardwick Tonalite—biotite tonalite to granodiorite gneiss
Dl	Devonian	Littleton Fm
Dl+Ops	Devonian	Littleton and Partridge Fms, interfolded
Dl+Ops	Devonian	Partridge Fm—interfolded Littleton and Partridge Fms
Dlf	Devonian	Littleton Fm—quartz-feldspar-garnet gneiss, probably felsic metavolcanic rock
Dlm	Devonian	Littleton Fm—calcitic marble
Dlo	Devonian	Littleton Fm—orthopyroxene-biotite gneiss, probably intermediate metavolcanic rock
Dmgr	Devonian	Muscovite-biotite granite
DOgr	Devonian/Ordovician	Alkalic granite in Franklin
Dpgr	Devonian	Peabody Granite—alkalic granite containing ferro-hornblende
Drgr	Devonian	Granite of Rattlesnake Hill pluton—biotite-granite and fine-grained riebeckite granite
Drh	Devonian	Hardwick Tonalite: Biotite-garnet-feldspar gneiss of Ragged Hill
DSdi	Devonian/Silurian	Diorite and tonalite
DSn	Devonian/Silurian	Newbury Volcanic Complex—undivided sedimentray and volcanic rocks
DSna	Devonian/Silurian	Newbury Volcanic Complex—porphyritic andesite, includes tuffaceous mudstone
DSnl	Devonian/Silurian	Newbury Volcanic Complex—basalt, andesite, rhyolite, and tuff
DSnr	Devonian/Silurian	Newbury Volcanic Complex—micrographic rhyolite
DSnu	Devonian/Silurian	Newbury Volcanic Complex—calcareous mudstone, red mudstone, and siliceous siltstone
DSw	Devonian/Silurian	Worcester Fm—carbonaceous slate and phyllite and minor metagraywacke
Dwm	Devonian	Wenham Monzonite—monzonite containing ferro-hornblende
DZl	Devonian	Lynn Volcanic Complex—rhyolite, agglomerate, and tuff
fgr	Unknown age	Fine-grained granite and granite porphyry

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area. —Continued

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
gb	Precambrian to Paleozoic	Hornblende-olivine gabbro
Cbw	Cambrian	Braintree Argillite and Weymouth Fm—argillite, with some rare limestone
Cg	Cambrian	Green Lodge Fm of Rhodes and Graves (1931)—quartzite and slate
Ch	Cambrian	Hoppin Fm—quartzite, argillite, and minor limestone
cu	Unknown age	Cumberlandite—rock containing magnetite, ilmenite, olivine, labradorite, and spinel
Dcgr	Devonian	Chelmsford Granite—muscovite-biotite granite
Dchgr	Devonian	Coys Hill Porphyritic Granite Gneiss—microcline granite gneiss
Dchh	Devonian	Coys Hill Porphyritic Granite Gneiss— hornblende gneiss inclusions
Dcygr	Devonian	Cherry Hill Granite—alaskite granite containing ferro-hornblende
Ddi	Devonian	Hardwick Tonalite: Biotite-hornblende diorite and quartz-bearing diorite
Ddn	Devonian	Hardwick Tonalite: Meladiorite and norite
Dfgd	Devonian	Fitchburg Complex—biotite granodiorite to tonalite gneiss
Dfgds	Devonian	Fitchburg Complex—biotite-muscovite granitic gneiss with mica schist and feldspathic granulite inclusions
Dfgr	Devonian	Fitchburg Complex—muscovite-biotite granite
Dfgrg	Devonian	Fitchburg Complex—biotite-muscovite granite to granodiorite gneiss
Dft	Devonian	Fitchburg Complex—biotite-hornblende tonalite inclusions
Dgd	Devonian	Granodiorite
Dgr	Devonian	Biotite-muscovite granite
Dhgr	Devonian	Hardwick Tonalite—porhyritic microcline-biotite granite gneiss
Dht	Devonian	Hardwick Tonalite—biotite tonalite to granodiorite gneiss
Dl	Devonian	Littleton Fm
Dl+Ops	Devonian	Littleton and Partridge Fms, interfolded
Dl+Ops	Devonian	Partridge Fm—interfolded Littleton and Partridge Fms
Dlf	Devonian	Littleton Fm—quartz-feldspar-garnet gneiss, probably felsic metavolcanic rock
Dlm	Devonian	Littleton Fm—calcitic marble
Dlo	Devonian	Littleton Fm—orthopyroxene-biotite gneiss, probably intermediate metavolcanic rock
Dmgr	Devonian	Muscovite-biotite granite
DOgr	Devonian/Ordovician	Alkalic granite in Franklin
Dpgr	Devonian	Peabody Granite—alkalic granite containing ferro-hornblende
Drgr	Devonian	Granite of Rattlesnake Hill pluton—biotite-granite and fine-grained riebeckite granite
Drh	Devonian	Hardwick Tonalite: Biotite-garnet-feldspar gneiss of Ragged Hill
DSdi	Devonian/Silurian	Diorite and tonalite
DSn	Devonian/Silurian	Newbury Volcanic Complex—undivided sedimentray and volcanic rocks
DSna	Devonian/Silurian	Newbury Volcanic Complex—porphyritic andesite, includes tuffaceous mudstone
DSnl	Devonian/Silurian	Newbury Volcanic Complex—basalt, andesite, rhyolite, and tuff
DSnr	Devonian/Silurian	Newbury Volcanic Complex—micrographic rhyolite
DSnu	Devonian/Silurian	Newbury Volcanic Complex—calcareous mudstone, red mudstone, and siliceous siltstone
DSw	Devonian/Silurian	Worcester Fm—carbonaceous slate and phyllite and minor metagraywacke
Dwm	Devonian	Wenham Monzonite—monzonite containing ferro-hornblende
DZl	Devonian	Lynn Volcanic Complex—rhyolite, agglomerate, and tuff

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area. —Continued

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
fgr	Unknown age	Fine-grained granite and granite porphyry
gb	Precambrian to Paleozoic	Hornblende-olivine gabbro
gd	Precambrian to Paleozoic	Granodiorite
gr	Precambrian to Paleozoic	Granite
grg	Devonian	Biotite granitic gneiss
hg	Precambrian to Paleozoic	Hornblende-plagioclase gneiss
igd	Precambrian to Paleozoic	Granodiorite of the Indian Head pluton—biotite granodiorite and hornblende-biotite tonalite
Jd	Jurassic	Diabase dikes and sills
Jsi	Jurassic	Silicified fault-breccia or strongly silicified metamorphic rocks
K	Cretaceous	Cretaceous sediments—clay, silt, sand, and gravel, mostly non-marine and near-shore
mgr	Precambrian to Silurian	Muscovite granite
Ogl	Ordovician	Glastonbury Gneiss—granitic gneiss
Ongb	Ordovician	Nahant Gabbro and gabbro at Salem Neck—labradorite-pyroxene gabbro, hornblende gabbro, and hornblende diorite
Opa	Ordovician	Partridge Fm—amphibolite
Opau	Ordovician	Partridge Fm—sillimanite-feldspar augen gneiss
Opbg	Ordovician	Partridge Fm—biotite gneiss
Opc	Ordovician	Pauchaug Gneiss—granitic gneiss
Opf	Ordovician	Partridge Fm—felsic gneiss, metavolcanic, and minor amphibolite
Ops	Ordovician	Partridge Fm—sulfidic mica schist and subordinate amphibolite
Opsa	Ordovician	Partridge Fm—sulfidic mica schist and abundant amphibolite
Opsc	Ordovician	Partridge Fm—sulfidic schist and abundant calc-silicate
Opsg	Ordovician	Partridge Fm—felsic gneiss and schist
Opu	Ordovician	Partridge Fm—ultramafic lenses, commonly hornblendite
Opv	Ordovician	Partridge Fm—mafic and felsic gneisses, metavolcanic, with calc-silicate granofels
Opvs	Ordovician	Partridge Fm—biotite gneiss, metavolcanic; minor amphibolite and sulfidic schist
OZf	Neoproterozoic	Fish Brook Gneiss—biotite-plagioclase quartz gneiss
OZm	Neoproterozoic	Marlboro Fm—amphibolite, biotite schist and gneiss, minor calc-silicate granofels and felsic granofels
OZma	Neoproterozoic	Massabesic Gneiss Complex—biotite feldspar paragneiss intruded by potassium-feldspar-rich gneiss
OZmg	Neoproterozoic	Marlboro Fm—feldspathic gneiss
OZn	Neoproterozoic	Nashoba Fm—sillimanite schist and gneiss, partly sulfidc, amphibolite, biotite gneiss, calc-silicate gneiss, and marble
OZnb	Neoproterozoic	Nashoba Fm: Boxford Mbr—massive amphibolite, minor biotite gneiss
OZq	Neoproterozoic	Quinebaug Fm—amphibolite, biotite, and hornblende gneiss, felsic gneiss, and calc-silicate gneiss
OZsh	Neoproterozoic	Shawsheen Gneiss—sillimanite gneiss, sulfidic at base; minor amphibolite
OZt	Neoproterozoic	Tatnic Hill Fm—sulfidic sillimanite schist, sillimanite schist and gneiss, biotite gneiss; minor amphibolite, calc-silicate gneiss and marble
OZtf	Neoproterozoic	Tatnic Hill Fm: Fly Pond Mbr—calc-silicate gneiss and marble

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area. —Continued

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
OZty	Neoproterozoic	Tatnic Hill Fm: Yantic Mbr—grey mica schist
Pcm	Pennsylvanian	Coal Mine Brook Fm—carbonaceous slate and garnet phyllite; lens of meta-anthracite; conglomerate and arkose
Pd	Pennsylvanian	Dighton Conglomerate—coarse conglomerate having sandy matrix; minor sandstone
Pgr	Pennsylvanian	Biotite granite, with magnetite-bearing pegmatite
Ph	Pennsylvanian	Harvard Conglomerate—conglomerate and chloritoid-hematite phyllite
Pp	Pennsylvanian	Pondville Conglomerate—quartz conglomerate having abundant sandy matrix; boulder conglomerate; arkose
Pr	Pennsylvanian	Rhode Island Fm—sandstone, graywacke, shale, and conglomerate; minor beds of meta-antracite
Prc	Pennsylvanian	Rhode Island Fm—conglomerate, sandstone, and graywacke
Pw	Pennsylvanian	Wamsutta Fm—red to pink conglomerate, graywacke, sandstone, and shale
Pwv	Pennsylvanian	Wamsutta Fm—rhyolite and mafic volcanic rocks
PZb	Unknown age	Bellingham Conglomerate—red and gray metamorphosed conglomerate, sandstone, graywacke, and shale
PzZc	Proterozoic Z to earliest Paleozoic	Cambridge Argillite—gray argillite and minor quartzite; rare sandstone and conglomerate
PzZr	Proterozoic Z to earliest Paleozoic	Roxbury Conglomerate—conglomerate, sandstone, siltstone, argillite, and melaphyre
PzZrb	Proterozoic Z to earliest Paleozoic	Roxbury Conglomerate—melaphyre
q	Unknown age	Massive quartz and silicified rock
qd	Precambrian to Phanerozoic	Quartz diorite
Sacgr	Silurian	Ayer Granite—Clinton facies, porphyritic biotite granite
Sagr	Silurian	Ayer Granite—granite to tonalite
Sb	Silurian	Berwick Fm—metamorphosed calcareous sandstone, silstone, and minor muscovite schist (1 polygon)
Sb	Silurian	Berwick Fm—metamorphosed calcareous sandstone, silstone, and minor muscovite schist
Sbs	Silurian	Berwick Fm—mica schist
Se	Silurian	Eliot Fm—phyllite and calcareous phyllite
Sfs	Silurian	Fitch Fm—sulfidic calc-silicate and minor sulfidic schist
Sfss	Silurian	Fitch Fm—sulfidic mica schist
Sgr	Silurian	Rusty-weathering biotite granite to granodiorite
Sngr	Silurian	Newburyport Complex—porphyritic granite with microcline phenocrysts
So	Silurian	Oakdale Fm—metamorphosed pelitic and calcareous siltsone and muscovite schist
SOad	Silurian	Ayer Granite—Devens-Long Pond facies, porphyritic gneissic biotite granite and granodiorite
SOagr	Silurian	Andover Granite—muscovite-biotite granite
SObgr	Silurian	Blue Hill Granite Porphyry—microperthite-quartz porphyry
SObo	Silurian	Boylston Schist—carbonaceous phyllite and schist, locally sulfidic; quartzite; calc-silicate beds
SOcb	Silurian	Cape Ann Complex: Beverly Syenite
SOcgr	Silurian	Cape Ann Complex—alkalic granite to quartz syenite containing ferro-hornblende
SOcsm	Silurian	Cape Ann Complex: Squam Granite—monzodiorite
SOk	Silurian	Kittery Fm—quartzite, partly calcareous; phyllite, schist

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area. —Continued

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
SOngd	Silurian	Newburyport Complex—tonalite and granodiorite
SOqgr	Silurian	Quincy Granite—alkalic granite containing riebeckite and aegirine
SOrh	Silurian	Reubens Hill Fm—amphibolite, hornblende-chlorite schist, and feldspathic schist; includes metamorphosed diorite
SOvh	Silurian	Vaughn Hills Quartzite—quartzite, phyllite, conglomerate, and chlorite schist
Sp	Silurian	Paxton Fm—biotite granofels, calc-silicate granofels, and sulfidic schist
Spa	Silurian	Paxton Fm—amphibolite
Spbc	Silurian	Paxton Fm—diopside calc-silicate granofels
Spbs	Silurian	Paxton Fm: Bigelow Brook Mbr—biotite granofels, sulfidic schist, and minor calc-silicate granofels
Spqr	Silurian	Paxton Fm—rusty-weathering sulfidic quartzite and sulfidic schist
Spso	Silurian	Paxton Fm: Southbridge Mbr—biotite granofels and calc-silicate granofels
Spsq	Silurian	Paxton Fm—sulfidic magnesian biotite and magnesian cordierite schist and sillimanite quartzite
Spss	Silurian	Paxton Fm—sulfidic mica schist
Ssaqd	Silurian	Straw Hollow Diorite and Assabet Quartz Diorite, undifferentiated—biotite-hornblende diorite and quartz diorite
Ssqd	Silurian	Sharpners Pond Diorite—biotite-hornblende tonalite and diorite
St	Silurian	Tower Hill Quartzite—quartzite and phyllite
Sts	Silurian	Tower Hill Quartzite—gray phyllite
SZtb	Silurian	Tadmuck Brook Schist—andalusite phyllite and sillimanite schist, partly sulfidic; local quartzite
T	Tertiary	Tertiary sediments—unconsolidated sand, silt, and clay in discontinuous patches
TRe	Triassic	Red arkosic conglomerate, sandstone, and siltstone
u	Precambrian to Phanerozoic	Serpentinite
Zagr	Neoproterozoic	Alaskite—mafic-poor gneissic granite, commonly containing muscovite
Zb	Proterozoic Z	Blackstone Group—undivided, quartzite, schist, phyllite, marble, and metavolcanic rocks
Zbq	Proterozoic Z	Blackstone Group: Quinnville Quartzite
Zbs	Proterozoic Z	Blackstone Group—mica schist and phyllite
Zbv	Proterozoic Z	Blackstone Group—greenstone and amphibolite
Zdgr	Proterozoic Z	Dedham Granite—granite; includes dioritic rock
Zdi	Proterozoic Z	Diorite—hornblende diorite metamorhosed in part to amphibolite and hornblende gneiss
Zdigb	Proterozoic Z	Diorite and gabbro—complex of diorite and gabbro, sub. metavolcanic rocks and intrusive granite and granodiorite
Zdngr	Proterozoic Z	Dedham Granite—granite to granodiorite
Zegr	Proterozoic Z	Esmond Granite—biotite granite
Zfgr	Proterozoic Z	Granite of the Fall River pluton—biotite granite, in part mafic poor
Zfm	Proterozoic Z	Felsic and mafic volcanic rocks
Zgb	Proterozoic Z	Gabbro—hornblende gabbro and hornblende-pyroxene gabbro metamorphosed in part to hornblende gneiss and amphibolite
Zgg	Proterozoic Z	Granite, gneiss, and schist, undivided—plutonic and metamorphic rocks
Zgmgd	Proterozoic Z	Grant Mills Granodiorite—porphyritic granodiorite

Appendix 1. Abbreviations and descriptions for bedrock units in and adjacent to the study area. —Continued

[Fm, formation; Mbr, member; bedrock unit abbreviations and descriptions are from Zen and others, 1983]

Bedrock unit abbreviation	Age	Bedrock unit descriptions
Zgn	Proterozoic Z	Biotite gneiss near New Bedford—feldspathic gneiss
Zgr	Proterozoic Z	Biotite granite
Zgs	Proterozoic Z	Gneiss and schist near New Bedford—hornblende and biotite schist and gneiss, amphibolite
Zhg	Proterozoic Z	Hope Valley Alaskite Gneiss—mafic-poor gneissic granite, locally containing muscovite
Zm	Proterozoic Z	Mattapan Volcanic Complex—rhyolite, melaphyre, agglomerate, and tuff
Zmgd	Proterozoic Z	Milford Granite—seriate to subporphyritic granite to granodiorite, locally gneissic
Zmgr	Proterozoic Z	Milford Granite—biotite granite, locally gneissic
Zp	Proterozoic Z	Plainfield Fm—quartzite, pelitic schist, minor calc-silicate rock and amphibolite
Zpg	Proterozoic Z	Ponaganset Gneiss—gneissic biotite granite containing megacrysts of microcline
Zpgr	Proterozoic Z	Porphyritic granite—seriate to porphyritic biotite granite with epidote and sphene and mafic inclusions
Zrdi	Proterozoic Z	Diorite at Rowley—hornblende diorite
Zsg	Proterozoic Z	Scituate Granite Gneiss—gneissic granite containing biotite
Zssy	Proterozoic Z	Sharon Syenite—syenite containing microperthite, oligoclase, and clinopyroxene, mixed with ferro-gabbro
Ztgd	Proterozoic Z	Topsfield Granodiorite—porphyritic granodiorite
Zv	Proterozoic Z	Metamorphosed mafic to felsic flow, and volcaniclastic and hypabyssal intrusive rocks
Zvf	Proterozoic Z	Metamorphosed felsic metavolcanic rocks
Zw	Proterozoic Z	Westboro Fm—quartzite, schist, calc-silicate quartzite, and amphibolite
Zwgr	Proterozoic Z	Westwood Granite

Appendix 2. Letter to Potential Participants in the Study

Appendix 2. Letter to potential participants in the study.

OMB Control Number 1028-0086

USGS Study on Arsenic and Uranium in Bedrock Wells of East Central Massachusetts

Dear Resident Well User:

The U.S. Geological Survey (USGS) and the Massachusetts Department of Environmental Protection (MDEP) are conducting a study of drinking water to assess the extent of possible elevated concentrations of naturally occurring arsenic and uranium in bedrock aquifers that provide drinking water in east central Massachusetts. The well at your address has been chosen by a random selection process to be included in the study.

The study, conducted by John Colman, U.S. Geological Survey (508 490 5027), will indicate relationships between arsenic and uranium concentrations and type of bedrock in which a well is drilled. This information will help guide future water-supply development, well-water testing, and estimates of total numbers of wells affected.

Your participation is completely voluntary, and results from your well will be kept completely confidential (by Exemption 9, well data is not subject to the Freedom of Information Act) and will only be used for the purpose of this study.

We will report results to you with information about health effects of drinking water greater than standards and ways to decrease concentrations. If you have any questions, please do not hesitate to contact the project leader John Colman at: (508) 490 5027.

Questionnaires will be mailed to a small number of the selected well addresses by the Massachusetts Department of Public Health (MDPH). The MDPH questionnaire offers a second program of biomonitoring for some participants concerned about uranium and arsenic effects on health. Participation in the MDPH program is also voluntary and is not required for well testing by USGS.

In Parts 1 and 3 of the survey we want to know a little about your water and where it comes from. In Part 2, there are instructions about how to collect a water sample. When you are done, please use the enclosed business reply envelope to mail your survey and water samples back to the USGS. **Please mail in the bottles and survey soon, if possible within 2 weeks. If it goes longer, however, we are still interested.**

PART 1 - Water Sources and Supplies

The majority of residential water supply wells in east-central Massachusetts are private wells that tap ground water aquifers in fractured bedrock formations. In the first part of this study, we would like to ask you a few questions about your water source and supply.

1. Is your home supplied with water from a private (bedrock) well?

   ☐ Yes (go to question 2)

   ☐ No. My house supply is town water or another source other than bedrock well.
   Please **STOP** here. You do not have to mail back bottles or a water sample.

Appendix 2. Letter to potential participants in the study.—Continued

2. Is your well water treated?

☐ Yes

What is the treatment? ______________________________

☐ No

3. How many people are in your household? *(This question is to determine the amount of water use in your household).*

______ People live in this household .

4. Do you use your well water for drinking water and/or cooking?

☐ Yes

☐ No, because of water quality issues (Select all that apply):

☐ **Arsenic**
☐ **Iron**
☐ **Manganese**
☐ **Other**____

☐ **Uranium**
☐ **Sediment**
☐ **Taste**

Part 2 - Water Sampling Instructions

Although collecting a water sample is a relatively simple task, there are several steps that must be taken to ensure accurate results. Please follow the instructions in steps 1-6 below to complete the next section of the survey.

Sampling Objective

The objective is to get a water sample that represents the water in the bedrock aquifer as closely as possible, so please select a tap that does not have treatment. Both bottles should be filled from the same faucet, one that does not have a water treatment system. Sample bottle screw threads and cap should not be contaminated with dirt from hands or the tap.

Once the bottles are filled, please mail the samples and questionnaire in the enclosed, prepaid business reply envelope.

Appendix 2. Letter to potential participants in the study.—Continued

Instructions

1. Collect your water sample **in the sample containers provided by the USGS**. Samples collected in any other container will not meet lab standards and cannot be processed.
2. **Choose a location to sample your water.** If you **do not** have any water treatment devices, such as a water softener or a reverse osmosis filter, take the sample from a cold water tap where you get your drinking water. If you **do** have treatment devices on your water system, (other than a whole-house filter for sediment) please locate a faucet which is attached to the water line before the treatment system.
3. Please avoid contamination of your samples, and do not touch the inside of the bottle or cap.
4. **Turn on the cold water and let it run for 1 minute** to flush the water out of the pipes. Turn the faucet down to a pencil size stream of water and fill the sample container.
5. Place the bottles and your completed survey in the enclosed postage-paid, business-reply envelope.
6. Mail the envelope to the USGS.

PART 3 - Location and Time of Water Sample

Please tell us where and when you collected the water for this sample.

☐ Basement Faucet

☐ Outside Spigot

☐ Bathroom Faucet

☐ Kitchen Faucet

☐ Other ________________________________

Date and time of sampling____________________________________

We would like to conduct follow-up sampling with a visit to a small number of participants. Would you be willing to participate in the follow-up visit?

☐ Yes, I would like to participate in a follow-up visit.
Please contact me by phone: ____________________________________
Or by email: ____

☐ No, I would not like to participate in a follow-up visit.

We would like to thank you for taking the time to participate in this important study.

PAPERWORK REDUCTION ACT STATEMENT: The Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.) requires us to inform you that this information is being collected to inform a study on arsenic and uranium in bedrock wells of east central Massachusetts. The estimated burden for this collection of information is estimated to average 20 minutes per response, including the time for reviewing instructions, answering questions, collecting water samples. The response to this request is voluntary. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB Control Number. Comments regarding the burden estimate or any other aspect of this collection of information should be directed to: John Colman at (508) 490 5027.

Appendix 3. Probability of Arsenic Exceeding a Given Concentration by Bedrock Unit

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Grouped bedrock units with elevated arsenic concentration			Bedrock unit abbreviation					
				Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.66442	0.60023	0.72414	0.03526	0.00377	0.17241	0.55522	0.27338	0.81066
2	0.52993	0.46620	0.59290	0.01398	0.00108	0.09179	0.36942	0.15070	0.64306
3	0.44855	0.38670	0.51167	0.00764	0.00049	0.06006	0.27105	0.09073	0.54658
4	0.39190	0.33202	0.45446	0.00484	0.00027	0.04334	0.21023	0.05795	0.48441
5	0.34942	0.29143	0.41117	0.00334	0.00017	0.03316	0.16912	0.03875	0.44042
6	0.31604	0.25983	0.37687	0.00244	0.00011	0.02639	0.13965	0.02687	0.40719
7	0.28893	0.23440	0.34879	0.00186	0.00008	0.02161	0.11763	0.01919	0.38091
8	0.26637	0.21342	0.32525	0.00146	0.00006	0.01809	0.10064	0.01406	0.35941
9	0.24723	0.19578	0.30515	0.00117	0.00004	0.01540	0.08721	0.01051	0.34138
10	**0.23076**	**0.18073**	**0.28772**	**0.00096**	**0.00003**	**0.01329**	**0.07637**	**0.00801**	**0.32594**
11	0.21641	0.16771	0.27242	0.00080	0.00003	0.01161	0.06748	0.00619	0.31252
12	0.20376	0.15633	0.25886	0.00068	0.00002	0.01024	0.06008	0.00486	0.30069
13	0.19253	0.14630	0.24673	0.00058	0.00002	0.00910	0.05384	0.00386	0.29017
14	0.18247	0.13739	0.23581	0.00050	0.00001	0.00815	0.04854	0.00310	0.28071
15	0.17341	0.12942	0.22590	0.00043	0.00001	0.00735	0.04399	0.00251	0.27214
16	0.16520	0.12225	0.21687	0.00038	0.00001	0.00666	0.04005	0.00205	0.26434
17	0.15772	0.11576	0.20860	0.00034	0.00001	0.00607	0.03661	0.00169	0.25718
18	0.15088	0.10986	0.20098	0.00030	0.00001	0.00555	0.03360	0.00140	0.25058
19	0.14459	0.10448	0.19395	0.00027	0.00001	0.00510	0.03094	0.00117	0.24447
20	0.13878	0.09954	0.18742	0.00024	0.00001	0.00470	0.02857	0.00099	0.23879
21	0.13341	0.09501	0.18135	0.00022	0.00001	0.00435	0.02647	0.00084	0.23349
22	0.12843	0.09082	0.17568	0.00020	0.00000	0.00403	0.02459	0.00071	0.22853
23	0.12379	0.08694	0.17037	0.00018	0.00000	0.00375	0.02289	0.00061	0.22387
24	0.11945	0.08334	0.16540	0.00016	0.00000	0.00350	0.02136	0.00052	0.21949
25	0.11540	0.08000	0.16072	0.00015	0.00000	0.00327	0.01998	0.00045	0.21535
26	0.11160	0.07687	0.15631	0.00014	0.00000	0.00307	0.01872	0.00039	0.21143
27	0.10802	0.07396	0.15215	0.00013	0.00000	0.00288	0.01758	0.00034	0.20772
28	0.10466	0.07123	0.14821	0.00012	0.00000	0.00271	0.01653	0.00030	0.20419
29	0.10149	0.06866	0.14448	0.00011	0.00000	0.00256	0.01557	0.00026	0.20083
30	0.09849	0.06625	0.14093	0.00010	0.00000	0.00241	0.01469	0.00023	0.19763
31	0.09565	0.06398	0.13756	0.00009	0.00000	0.00228	0.01388	0.00020	0.19458
32	0.09296	0.06184	0.13436	0.00009	0.00000	0.00216	0.01313	0.00018	0.19166
33	0.09040	0.05982	0.13130	0.00008	0.00000	0.00205	0.01244	0.00016	0.18886
34	0.08798	0.05791	0.12839	0.00008	0.00000	0.00195	0.01180	0.00014	0.18618
35	0.08567	0.05609	0.12560	0.00007	0.00000	0.00185	0.01120	0.00012	0.18361

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Grouped bedrock units with elevated arsenic concentration			Bedrock unit abbreviation					
				Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.08346	0.05438	0.12293	0.00007	0.00000	0.00176	0.01065	0.00011	0.18113
37	0.08136	0.05274	0.12038	0.00006	0.00000	0.00168	0.01014	0.00010	0.17875
38	0.07936	0.05119	0.11793	0.00006	0.00000	0.00160	0.00966	0.00009	0.17646
39	0.07744	0.04972	0.11558	0.00006	0.00000	0.00153	0.00921	0.00008	0.17425
40	0.07561	0.04831	0.11332	0.00005	0.00000	0.00146	0.00879	0.00007	0.17212
41	0.07385	0.04697	0.11115	0.00005	0.00000	0.00140	0.00840	0.00006	0.17006
42	0.07216	0.04569	0.10906	0.00005	0.00000	0.00134	0.00803	0.00006	0.16807
43	0.07055	0.04446	0.10705	0.00004	0.00000	0.00129	0.00768	0.00005	0.16615
44	0.06900	0.04329	0.10512	0.00004	0.00000	0.00123	0.00736	0.00005	0.16428
45	0.06750	0.04217	0.10325	0.00004	0.00000	0.00119	0.00705	0.00004	0.16248
46	0.06607	0.04110	0.10144	0.00004	0.00000	0.00114	0.00676	0.00004	0.16073
47	0.06469	0.04007	0.09970	0.00004	0.00000	0.00110	0.00649	0.00004	0.15903
48	0.06336	0.03908	0.09802	0.00003	0.00000	0.00105	0.00623	0.00003	0.15738
49	0.06208	0.03813	0.09639	0.00003	0.00000	0.00102	0.00599	0.00003	0.15578
50	0.06084	0.03722	0.09481	0.00003	0.00000	0.00098	0.00576	0.00003	0.15423
55	0.05526	0.03316	0.08765	0.00002	0.00000	0.00082	0.00478	0.00002	0.14706
60	0.05054	0.02978	0.08147	0.00002	0.00000	0.00070	0.00402	0.00001	0.14075
65	0.04647	0.02692	0.07609	0.00002	0.00000	0.00060	0.00341	0.00001	0.13514
70	0.04295	0.02447	0.07136	0.00001	0.00000	0.00052	0.00293	0.00001	0.13011
75	0.03987	0.02237	0.06716	0.00001	0.00000	0.00046	0.00253	0.00000	0.12556
80	0.03715	0.02054	0.06341	0.00001	0.00000	0.00040	0.00221	0.00000	0.12143
85	0.03474	0.01894	0.06005	0.00001	0.00000	0.00036	0.00194	0.00000	0.11764
90	0.03258	0.01752	0.05700	0.00001	0.00000	0.00032	0.00171	0.00000	0.11416
95	0.03065	0.01627	0.05424	0.00001	0.00000	0.00029	0.00152	0.00000	0.11094
100	0.02890	0.01515	0.05172	0.00001	0.00000	0.00026	0.00136	0.00000	0.10796
110	0.02587	0.01325	0.04729	0.00000	0.00000	0.00021	0.00109	0.00000	0.10259
120	0.02334	0.01170	0.04351	0.00000	0.00000	0.00018	0.00090	0.00000	0.09788
130	0.02120	0.01041	0.04026	0.00000	0.00000	0.00015	0.00074	0.00000	0.09370
140	0.01937	0.00932	0.03744	0.00000	0.00000	0.00013	0.00062	0.00000	0.08997
150	0.01779	0.00841	0.03495	0.00000	0.00000	0.00011	0.00053	0.00000	0.08660
160	0.01641	0.00762	0.03275	0.00000	0.00000	0.00010	0.00045	0.00000	0.08354
170	0.01520	0.00694	0.03079	0.00000	0.00000	0.00009	0.00039	0.00000	0.08075
180	0.01413	0.00635	0.02904	0.00000	0.00000	0.00008	0.00034	0.00000	0.07819
190	0.01318	0.00583	0.02746	0.00000	0.00000	0.00007	0.00030	0.00000	0.07582
200	0.01233	0.00538	0.02602	0.00000	0.00000	0.00006	0.00026	0.00000	0.07364

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Grouped bedrock units with elevated arsenic concentration			Bedrock unit abbreviation					
				Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.01157	0.00497	0.02472	0.00000	0.00000	0.00005	0.00023	0.00000	0.07161
220	0.01087	0.00461	0.02352	0.00000	0.00000	0.00005	0.00020	0.00000	0.06971
230	0.01025	0.00429	0.02243	0.00000	0.00000	0.00004	0.00018	0.00000	0.06794
240	0.00968	0.00400	0.02142	0.00000	0.00000	0.00004	0.00016	0.00000	0.06628
250	0.00916	0.00374	0.02050	0.00000	0.00000	0.00004	0.00015	0.00000	0.06472
260	0.00868	0.00350	0.01964	0.00000	0.00000	0.00003	0.00013	0.00000	0.06325
270	0.00824	0.00329	0.01884	0.00000	0.00000	0.00003	0.00012	0.00000	0.06186
280	0.00784	0.00309	0.01810	0.00000	0.00000	0.00003	0.00011	0.00000	0.06055
290	0.00747	0.00291	0.01740	0.00000	0.00000	0.00003	0.00010	0.00000	0.05930
300	0.00712	0.00275	0.01676	0.00000	0.00000	0.00002	0.00009	0.00000	0.05811

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.23792	0.07581	0.50313	0.16282	0.07832	0.29137	0.63210	0.44055	0.79514
2	0.19207	0.05460	0.44482	0.07879	0.02495	0.19331	0.51498	0.33884	0.68819
3	0.16795	0.04320	0.41687	0.04795	0.01088	0.15020	0.44518	0.27992	0.62072
4	0.15207	0.03587	0.39961	0.03262	0.00562	0.12468	0.39654	0.23959	0.57260
5	0.14047	0.03069	0.38756	0.02373	0.00322	0.10742	0.35986	0.20970	0.53578
6	0.13144	0.02681	0.37852	0.01807	0.00199	0.09480	0.33080	0.18642	0.50628
7	0.12413	0.02380	0.37140	0.01422	0.00130	0.08510	0.30699	0.16769	0.48187
8	0.11803	0.02137	0.36559	0.01148	0.00089	0.07737	0.28700	0.15224	0.46118
9	0.11283	0.01938	0.36074	0.00946	0.00063	0.07103	0.26990	0.13926	0.44331
10	**0.10832**	**0.01771**	**0.35659**	**0.00792**	**0.00046**	**0.06573**	**0.25505**	**0.12819**	**0.42764**
11	0.10435	0.01630	0.35299	0.00672	0.00034	0.06122	0.24199	0.11862	0.41375
12	0.10082	0.01508	0.34983	0.00577	0.00026	0.05733	0.23039	0.11026	0.40129
13	0.09765	0.01402	0.34701	0.00501	0.00020	0.05393	0.22000	0.10291	0.39003
14	0.09478	0.01309	0.34449	0.00438	0.00015	0.05093	0.21063	0.09638	0.37979
15	0.09217	0.01227	0.34221	0.00386	0.00012	0.04827	0.20211	0.09055	0.37040
16	0.08977	0.01154	0.34013	0.00342	0.00010	0.04589	0.19434	0.08530	0.36175
17	0.08756	0.01088	0.33823	0.00305	0.00008	0.04374	0.18720	0.08057	0.35374
18	0.08552	0.01029	0.33647	0.00274	0.00007	0.04179	0.18063	0.07627	0.34630
19	0.08361	0.00975	0.33485	0.00247	0.00005	0.04001	0.17454	0.07235	0.33935
20	0.08184	0.00926	0.33335	0.00224	0.00005	0.03839	0.16889	0.06877	0.33285
21	0.08018	0.00882	0.33194	0.00203	0.00004	0.03689	0.16363	0.06547	0.32674
22	0.07862	0.00841	0.33062	0.00185	0.00003	0.03551	0.15871	0.06244	0.32098
23	0.07715	0.00803	0.32939	0.00170	0.00003	0.03423	0.15410	0.05964	0.31555
24	0.07576	0.00768	0.32823	0.00156	0.00002	0.03305	0.14977	0.05704	0.31040
25	0.07445	0.00736	0.32713	0.00143	0.00002	0.03194	0.14569	0.05463	0.30552
26	0.07320	0.00706	0.32609	0.00132	0.00002	0.03091	0.14185	0.05238	0.30088
27	0.07202	0.00679	0.32511	0.00123	0.00001	0.02995	0.13821	0.05028	0.29646
28	0.07089	0.00653	0.32417	0.00114	0.00001	0.02904	0.13477	0.04832	0.29224
29	0.06982	0.00629	0.32328	0.00106	0.00001	0.02819	0.13151	0.04648	0.28821
30	0.06880	0.00606	0.32243	0.00099	0.00001	0.02739	0.12841	0.04476	0.28435
31	0.06782	0.00585	0.32162	0.00092	0.00001	0.02663	0.12545	0.04314	0.28065
32	0.06688	0.00565	0.32084	0.00086	0.00001	0.02591	0.12264	0.04161	0.27711
33	0.06598	0.00546	0.32010	0.00081	0.00001	0.02523	0.11996	0.04017	0.27370
34	0.06511	0.00528	0.31939	0.00076	0.00001	0.02459	0.11740	0.03881	0.27042
35	0.06428	0.00511	0.31870	0.00071	0.00001	0.02398	0.11494	0.03752	0.26726

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.06348	0.00495	0.31804	0.00067	0.00000	0.02339	0.11260	0.03631	0.26422
37	0.06271	0.00480	0.31741	0.00063	0.00000	0.02284	0.11035	0.03515	0.26128
38	0.06197	0.00466	0.31680	0.00060	0.00000	0.02231	0.10819	0.03405	0.25844
39	0.06125	0.00452	0.31621	0.00056	0.00000	0.02181	0.10612	0.03301	0.25570
40	0.06056	0.00439	0.31564	0.00053	0.00000	0.02132	0.10412	0.03202	0.25305
41	0.05989	0.00427	0.31509	0.00050	0.00000	0.02086	0.10220	0.03108	0.25048
42	0.05924	0.00415	0.31455	0.00048	0.00000	0.02042	0.10036	0.03018	0.24799
43	0.05861	0.00404	0.31404	0.00045	0.00000	0.02000	0.09858	0.02932	0.24558
44	0.05801	0.00393	0.31354	0.00043	0.00000	0.01959	0.09686	0.02850	0.24324
45	0.05742	0.00383	0.31305	0.00041	0.00000	0.01920	0.09521	0.02771	0.24097
46	0.05685	0.00374	0.31258	0.00039	0.00000	0.01882	0.09361	0.02696	0.23876
47	0.05629	0.00364	0.31213	0.00037	0.00000	0.01846	0.09206	0.02624	0.23661
48	0.05575	0.00355	0.31168	0.00035	0.00000	0.01811	0.09057	0.02556	0.23452
49	0.05523	0.00347	0.31125	0.00034	0.00000	0.01778	0.08912	0.02490	0.23249
50	0.05472	0.00338	0.31083	0.00032	0.00000	0.01745	0.08772	0.02426	0.23051
55	0.05236	0.00302	0.30889	0.00026	0.00000	0.01600	0.08133	0.02145	0.22133
60	0.05028	0.00271	0.30718	0.00021	0.00000	0.01476	0.07581	0.01912	0.21319
65	0.04843	0.00246	0.30564	0.00018	0.00000	0.01370	0.07099	0.01717	0.20589
70	0.04676	0.00224	0.30426	0.00015	0.00000	0.01277	0.06674	0.01551	0.19930
75	0.04525	0.00205	0.30300	0.00012	0.00000	0.01196	0.06297	0.01409	0.19331
80	0.04387	0.00189	0.30185	0.00011	0.00000	0.01124	0.05959	0.01286	0.18782
85	0.04261	0.00175	0.30079	0.00009	0.00000	0.01060	0.05654	0.01178	0.18277
90	0.04145	0.00162	0.29981	0.00008	0.00000	0.01003	0.05378	0.01084	0.17810
95	0.04037	0.00151	0.29890	0.00007	0.00000	0.00951	0.05128	0.01001	0.17376
100	0.03937	0.00141	0.29805	0.00006	0.00000	0.00905	0.04898	0.00928	0.16972
110	0.03757	0.00124	0.29650	0.00005	0.00000	0.00823	0.04494	0.00803	0.16240
120	0.03598	0.00111	0.29514	0.00004	0.00000	0.00754	0.04149	0.00702	0.15593
130	0.03457	0.00099	0.29391	0.00003	0.00000	0.00696	0.03851	0.00620	0.15015
140	0.03330	0.00089	0.29280	0.00003	0.00000	0.00645	0.03590	0.00551	0.14494
150	0.03215	0.00081	0.29179	0.00002	0.00000	0.00601	0.03361	0.00493	0.14022
160	0.03111	0.00074	0.29086	0.00002	0.00000	0.00562	0.03158	0.00443	0.13591
170	0.03016	0.00068	0.29000	0.00002	0.00000	0.00527	0.02976	0.00401	0.13195
180	0.02928	0.00063	0.28921	0.00001	0.00000	0.00497	0.02813	0.00364	0.12830
190	0.02848	0.00058	0.28847	0.00001	0.00000	0.00469	0.02665	0.00332	0.12492
200	0.02773	0.00054	0.28778	0.00001	0.00000	0.00444	0.02531	0.00304	0.12178

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.02703	0.00050	0.28713	0.00001	0.00000	0.00422	0.02409	0.00280	0.11885
220	0.02638	0.00047	0.28652	0.00001	0.00000	0.00401	0.02297	0.00258	0.11610
230	0.02577	0.00044	0.28595	0.00001	0.00000	0.00382	0.02195	0.00238	0.11353
240	0.02519	0.00041	0.28541	0.00001	0.00000	0.00365	0.02100	0.00221	0.11110
250	0.02465	0.00038	0.28489	0.00001	0.00000	0.00349	0.02012	0.00206	0.10881
260	0.02414	0.00036	0.28440	0.00001	0.00000	0.00335	0.01931	0.00192	0.10665
270	0.02366	0.00034	0.28393	0.00000	0.00000	0.00321	0.01856	0.00179	0.10460
280	0.02320	0.00032	0.28349	0.00000	0.00000	0.00308	0.01786	0.00167	0.10266
290	0.02277	0.00031	0.28307	0.00000	0.00000	0.00297	0.01720	0.00157	0.10080
300	0.02236	0.00029	0.28266	0.00000	0.00000	0.00286	0.01658	0.00147	0.09904

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			SOagr			Spsq		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.43165	0.15898	0.74354	0.32722	0.14632	0.56242	0.06350	0.01045	0.22900
2	0.06143	0.01062	0.21710	0.22397	0.08084	0.45292	0.02471	0.00212	0.14221
3	0.00952	0.00061	0.07257	0.17337	0.05237	0.39760	0.01316	0.00066	0.10868
4	0.00179	0.00004	0.02970	0.14228	0.03691	0.36223	0.00811	0.00026	0.09011
5	0.00040	0.00000	0.01393	0.12094	0.02746	0.33686	0.00546	0.00012	0.07803
6	0.00010	0.00000	0.00719	0.10525	0.02121	0.31738	0.00390	0.00006	0.06940
7	0.00003	0.00000	0.00399	0.09318	0.01686	0.30173	0.00291	0.00003	0.06287
8	0.00001	0.00000	0.00234	0.08358	0.01370	0.28876	0.00224	0.00002	0.05771
9	0.00000	0.00000	0.00143	0.07575	0.01134	0.27773	0.00177	0.00001	0.05351
10	**0.00000**	**0.00000**	**0.00091**	**0.06923**	**0.00952**	**0.26820**	**0.00142**	**0.00001**	**0.05001**
11	0.00000	0.00000	0.00060	0.06371	0.00809	0.25983	0.00117	0.00001	0.04704
12	0.00000	0.00000	0.00040	0.05898	0.00695	0.25239	0.00097	0.00000	0.04447
13	0.00000	0.00000	0.00028	0.05487	0.00602	0.24571	0.00082	0.00000	0.04223
14	0.00000	0.00000	0.00020	0.05127	0.00527	0.23967	0.00069	0.00000	0.04026
15	0.00000	0.00000	0.00014	0.04809	0.00463	0.23416	0.00060	0.00000	0.03850
16	0.00000	0.00000	0.00010	0.04526	0.00410	0.22911	0.00052	0.00000	0.03692
17	0.00000	0.00000	0.00008	0.04273	0.00366	0.22445	0.00045	0.00000	0.03549
18	0.00000	0.00000	0.00006	0.04045	0.00327	0.22013	0.00040	0.00000	0.03420
19	0.00000	0.00000	0.00004	0.03838	0.00294	0.21611	0.00035	0.00000	0.03301
20	0.00000	0.00000	0.00003	0.03650	0.00266	0.21236	0.00031	0.00000	0.03192
21	0.00000	0.00000	0.00003	0.03478	0.00241	0.20884	0.00028	0.00000	0.03092
22	0.00000	0.00000	0.00002	0.03321	0.00219	0.20553	0.00025	0.00000	0.02999
23	0.00000	0.00000	0.00002	0.03176	0.00200	0.20241	0.00022	0.00000	0.02912
24	0.00000	0.00000	0.00001	0.03042	0.00183	0.19946	0.00020	0.00000	0.02832
25	0.00000	0.00000	0.00001	0.02918	0.00168	0.19667	0.00018	0.00000	0.02756
26	0.00000	0.00000	0.00001	0.02803	0.00155	0.19401	0.00017	0.00000	0.02686
27	0.00000	0.00000	0.00001	0.02695	0.00143	0.19149	0.00015	0.00000	0.02620
28	0.00000	0.00000	0.00001	0.02595	0.00132	0.18908	0.00014	0.00000	0.02557
29	0.00000	0.00000	0.00000	0.02502	0.00123	0.18678	0.00013	0.00000	0.02498
30	0.00000	0.00000	0.00000	0.02414	0.00114	0.18458	0.00012	0.00000	0.02443
31	0.00000	0.00000	0.00000	0.02332	0.00106	0.18247	0.00011	0.00000	0.02390
32	0.00000	0.00000	0.00000	0.02254	0.00099	0.18045	0.00010	0.00000	0.02340
33	0.00000	0.00000	0.00000	0.02181	0.00092	0.17851	0.00009	0.00000	0.02292
34	0.00000	0.00000	0.00000	0.02112	0.00086	0.17665	0.00009	0.00000	0.02247
35	0.00000	0.00000	0.00000	0.02047	0.00081	0.17485	0.00008	0.00000	0.02204

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			SOagr			Spsq		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00000	0.00000	0.00000	0.01986	0.00076	0.17312	0.00007	0.00000	0.02162
37	0.00000	0.00000	0.00000	0.01927	0.00071	0.17145	0.00007	0.00000	0.02123
38	0.00000	0.00000	0.00000	0.01872	0.00067	0.16984	0.00006	0.00000	0.02085
39	0.00000	0.00000	0.00000	0.01819	0.00063	0.16828	0.00006	0.00000	0.02049
40	0.00000	0.00000	0.00000	0.01769	0.00060	0.16678	0.00006	0.00000	0.02014
41	0.00000	0.00000	0.00000	0.01721	0.00056	0.16532	0.00005	0.00000	0.01981
42	0.00000	0.00000	0.00000	0.01675	0.00053	0.16390	0.00005	0.00000	0.01949
43	0.00000	0.00000	0.00000	0.01632	0.00050	0.16253	0.00005	0.00000	0.01918
44	0.00000	0.00000	0.00000	0.01590	0.00048	0.16120	0.00004	0.00000	0.01888
45	0.00000	0.00000	0.00000	0.01551	0.00045	0.15991	0.00004	0.00000	0.01860
46	0.00000	0.00000	0.00000	0.01512	0.00043	0.15866	0.00004	0.00000	0.01832
47	0.00000	0.00000	0.00000	0.01476	0.00041	0.15744	0.00004	0.00000	0.01806
48	0.00000	0.00000	0.00000	0.01441	0.00039	0.15625	0.00003	0.00000	0.01780
49	0.00000	0.00000	0.00000	0.01408	0.00037	0.15509	0.00003	0.00000	0.01755
50	0.00000	0.00000	0.00000	0.01375	0.00035	0.15397	0.00003	0.00000	0.01731
55	0.00000	0.00000	0.00000	0.01232	0.00028	0.14875	0.00002	0.00000	0.01622
60	0.00000	0.00000	0.00000	0.01112	0.00022	0.14412	0.00002	0.00000	0.01527
65	0.00000	0.00000	0.00000	0.01011	0.00018	0.13996	0.00002	0.00000	0.01445
70	0.00000	0.00000	0.00000	0.00925	0.00015	0.13619	0.00001	0.00000	0.01373
75	0.00000	0.00000	0.00000	0.00851	0.00013	0.13277	0.00001	0.00000	0.01308
80	0.00000	0.00000	0.00000	0.00786	0.00011	0.12962	0.00001	0.00000	0.01251
85	0.00000	0.00000	0.00000	0.00729	0.00009	0.12673	0.00001	0.00000	0.01198
90	0.00000	0.00000	0.00000	0.00679	0.00008	0.12405	0.00001	0.00000	0.01151
95	0.00000	0.00000	0.00000	0.00634	0.00007	0.12155	0.00001	0.00000	0.01108
100	0.00000	0.00000	0.00000	0.00594	0.00006	0.11922	0.00000	0.00000	0.01068
110	0.00000	0.00000	0.00000	0.00526	0.00005	0.11500	0.00000	0.00000	0.00998
120	0.00000	0.00000	0.00000	0.00470	0.00004	0.11124	0.00000	0.00000	0.00938
130	0.00000	0.00000	0.00000	0.00423	0.00003	0.10788	0.00000	0.00000	0.00886
140	0.00000	0.00000	0.00000	0.00383	0.00002	0.10484	0.00000	0.00000	0.00839
150	0.00000	0.00000	0.00000	0.00349	0.00002	0.10207	0.00000	0.00000	0.00798
160	0.00000	0.00000	0.00000	0.00320	0.00002	0.09954	0.00000	0.00000	0.00762
170	0.00000	0.00000	0.00000	0.00295	0.00001	0.09721	0.00000	0.00000	0.00729
180	0.00000	0.00000	0.00000	0.00272	0.00001	0.09505	0.00000	0.00000	0.00699
190	0.00000	0.00000	0.00000	0.00253	0.00001	0.09305	0.00000	0.00000	0.00671
200	0.00000	0.00000	0.00000	0.00235	0.00001	0.09118	0.00000	0.00000	0.00646

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			SOagr			Spsq		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00000	0.00000	0.00000	0.00220	0.00001	0.08942	0.00000	0.00000	0.00623
220	0.00000	0.00000	0.00000	0.00206	0.00001	0.08778	0.00000	0.00000	0.00602
230	0.00000	0.00000	0.00000	0.00193	0.00001	0.08624	0.00000	0.00000	0.00583
240	0.00000	0.00000	0.00000	0.00182	0.00000	0.08478	0.00000	0.00000	0.00564
250	0.00000	0.00000	0.00000	0.00171	0.00000	0.08339	0.00000	0.00000	0.00547
260	0.00000	0.00000	0.00000	0.00162	0.00000	0.08208	0.00000	0.00000	0.00531
270	0.00000	0.00000	0.00000	0.00153	0.00000	0.08084	0.00000	0.00000	0.00517
280	0.00000	0.00000	0.00000	0.00145	0.00000	0.07966	0.00000	0.00000	0.00503
290	0.00000	0.00000	0.00000	0.00138	0.00000	0.07853	0.00000	0.00000	0.00489
300	0.00000	0.00000	0.00000	0.00131	0.00000	0.07745	0.00000	0.00000	0.00477

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			SZtb		
	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.23273	0.06670	0.51638	0.64322	0.38238	0.84930	0.44216	0.31151	0.57949
2	0.09457	0.01492	0.32491	0.40139	0.19993	0.63395	0.26095	0.15832	0.38996
3	0.04903	0.00450	0.24303	0.27074	0.10603	0.51066	0.17621	0.09343	0.29462
4	0.02895	0.00165	0.19660	0.19308	0.05819	0.43523	0.12812	0.06020	0.23651
5	0.01857	0.00069	0.16620	0.14340	0.03328	0.38371	0.09772	0.04117	0.19710
6	0.01262	0.00032	0.14451	0.10983	0.01980	0.34569	0.07710	0.02941	0.16851
7	0.00896	0.00016	0.12816	0.08619	0.01221	0.31611	0.06240	0.02172	0.14678
8	0.00658	0.00008	0.11533	0.06898	0.00776	0.29222	0.05152	0.01648	0.12970
9	0.00496	0.00005	0.10495	0.05611	0.00507	0.27240	0.04323	0.01277	0.11591
10	**0.00382**	**0.00003**	**0.09636**	**0.04628**	**0.00339**	**0.25560**	**0.03676**	**0.01009**	**0.10455**
11	0.00300	0.00002	0.08913	0.03863	0.00232	0.24112	0.03161	0.00809	0.09504
12	0.00239	0.00001	0.08294	0.03257	0.00162	0.22848	0.02744	0.00657	0.08696
13	0.00194	0.00001	0.07758	0.02771	0.00115	0.21731	0.02403	0.00540	0.08001
14	0.00159	0.00000	0.07289	0.02377	0.00082	0.20735	0.02119	0.00449	0.07397
15	0.00131	0.00000	0.06874	0.02053	0.00060	0.19840	0.01880	0.00376	0.06869
16	0.00110	0.00000	0.06505	0.01785	0.00044	0.19031	0.01679	0.00318	0.06403
17	0.00092	0.00000	0.06174	0.01561	0.00033	0.18294	0.01506	0.00271	0.05988
18	0.00078	0.00000	0.05875	0.01372	0.00025	0.17620	0.01358	0.00232	0.05618
19	0.00067	0.00000	0.05604	0.01212	0.00019	0.17000	0.01229	0.00200	0.05284
20	0.00058	0.00000	0.05357	0.01076	0.00015	0.16427	0.01117	0.00174	0.04984
21	0.00050	0.00000	0.05131	0.00958	0.00011	0.15897	0.01019	0.00151	0.04711
22	0.00043	0.00000	0.04923	0.00857	0.00009	0.15403	0.00932	0.00133	0.04462
23	0.00038	0.00000	0.04731	0.00769	0.00007	0.14943	0.00856	0.00117	0.04235
24	0.00033	0.00000	0.04554	0.00693	0.00006	0.14512	0.00787	0.00103	0.04026
25	0.00029	0.00000	0.04389	0.00625	0.00004	0.14108	0.00727	0.00091	0.03834
26	0.00026	0.00000	0.04236	0.00567	0.00004	0.13728	0.00672	0.00081	0.03657
27	0.00023	0.00000	0.04093	0.00515	0.00003	0.13370	0.00623	0.00072	0.03493
28	0.00021	0.00000	0.03959	0.00468	0.00002	0.13032	0.00579	0.00065	0.03341
29	0.00018	0.00000	0.03833	0.00428	0.00002	0.12713	0.00539	0.00058	0.03200
30	0.00016	0.00000	0.03715	0.00391	0.00002	0.12409	0.00503	0.00052	0.03068
31	0.00015	0.00000	0.03604	0.00358	0.00001	0.12122	0.00470	0.00047	0.02945
32	0.00013	0.00000	0.03499	0.00329	0.00001	0.11848	0.00440	0.00043	0.02830
33	0.00012	0.00000	0.03400	0.00303	0.00001	0.11588	0.00412	0.00039	0.02722
34	0.00011	0.00000	0.03306	0.00279	0.00001	0.11339	0.00387	0.00035	0.02620
35	0.00010	0.00000	0.03217	0.00258	0.00001	0.11102	0.00364	0.00032	0.02525

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			SZtb		
	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00009	0.00000	0.03133	0.00239	0.00001	0.10875	0.00342	0.00029	0.02435
37	0.00008	0.00000	0.03053	0.00221	0.00000	0.10658	0.00323	0.00027	0.02351
38	0.00008	0.00000	0.02977	0.00205	0.00000	0.10450	0.00305	0.00025	0.02271
39	0.00007	0.00000	0.02904	0.00191	0.00000	0.10251	0.00288	0.00023	0.02195
40	0.00006	0.00000	0.02834	0.00177	0.00000	0.10059	0.00272	0.00021	0.02123
41	0.00006	0.00000	0.02768	0.00165	0.00000	0.09875	0.00258	0.00019	0.02055
42	0.00005	0.00000	0.02705	0.00154	0.00000	0.09698	0.00244	0.00018	0.01991
43	0.00005	0.00000	0.02644	0.00144	0.00000	0.09527	0.00232	0.00016	0.01930
44	0.00005	0.00000	0.02586	0.00135	0.00000	0.09363	0.00220	0.00015	0.01871
45	0.00004	0.00000	0.02530	0.00126	0.00000	0.09205	0.00210	0.00014	0.01816
46	0.00004	0.00000	0.02477	0.00118	0.00000	0.09052	0.00199	0.00013	0.01763
47	0.00004	0.00000	0.02426	0.00111	0.00000	0.08905	0.00190	0.00012	0.01712
48	0.00003	0.00000	0.02376	0.00104	0.00000	0.08762	0.00181	0.00011	0.01664
49	0.00003	0.00000	0.02329	0.00098	0.00000	0.08624	0.00173	0.00010	0.01618
50	0.00003	0.00000	0.02283	0.00092	0.00000	0.08491	0.00165	0.00010	0.01574
55	0.00002	0.00000	0.02078	0.00069	0.00000	0.07884	0.00132	0.00007	0.01380
60	0.00002	0.00000	0.01905	0.00053	0.00000	0.07360	0.00107	0.00005	0.01222
65	0.00001	0.00000	0.01757	0.00041	0.00000	0.06904	0.00089	0.00004	0.01090
70	0.00001	0.00000	0.01630	0.00032	0.00000	0.06502	0.00074	0.00003	0.00980
75	0.00001	0.00000	0.01519	0.00026	0.00000	0.06145	0.00062	0.00002	0.00886
80	0.00001	0.00000	0.01421	0.00021	0.00000	0.05826	0.00053	0.00002	0.00805
85	0.00000	0.00000	0.01334	0.00017	0.00000	0.05539	0.00045	0.00001	0.00736
90	0.00000	0.00000	0.01256	0.00014	0.00000	0.05279	0.00039	0.00001	0.00675
95	0.00000	0.00000	0.01186	0.00011	0.00000	0.05042	0.00034	0.00001	0.00622
100	0.00000	0.00000	0.01124	0.00010	0.00000	0.04826	0.00030	0.00001	0.00575
110	0.00000	0.00000	0.01015	0.00007	0.00000	0.04444	0.00023	0.00001	0.00496
120	0.00000	0.00000	0.00923	0.00005	0.00000	0.04118	0.00018	0.00000	0.00432
130	0.00000	0.00000	0.00846	0.00004	0.00000	0.03836	0.00015	0.00000	0.00380
140	0.00000	0.00000	0.00780	0.00003	0.00000	0.03589	0.00012	0.00000	0.00337
150	0.00000	0.00000	0.00722	0.00002	0.00000	0.03372	0.00010	0.00000	0.00301
160	0.00000	0.00000	0.00672	0.00002	0.00000	0.03178	0.00008	0.00000	0.00271
170	0.00000	0.00000	0.00628	0.00001	0.00000	0.03005	0.00007	0.00000	0.00245
180	0.00000	0.00000	0.00588	0.00001	0.00000	0.02850	0.00006	0.00000	0.00222
190	0.00000	0.00000	0.00553	0.00001	0.00000	0.02709	0.00005	0.00000	0.00203
200	0.00000	0.00000	0.00522	0.00001	0.00000	0.02581	0.00004	0.00000	0.00186

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			SZtb		
	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00000	0.00000	0.00493	0.00001	0.00000	0.02464	0.00004	0.00000	0.00171
220	0.00000	0.00000	0.00467	0.00001	0.00000	0.02356	0.00003	0.00000	0.00158
230	0.00000	0.00000	0.00444	0.00000	0.00000	0.02257	0.00003	0.00000	0.00146
240	0.00000	0.00000	0.00422	0.00000	0.00000	0.02166	0.00003	0.00000	0.00135
250	0.00000	0.00000	0.00402	0.00000	0.00000	0.02082	0.00002	0.00000	0.00126
260	0.00000	0.00000	0.00384	0.00000	0.00000	0.02003	0.00002	0.00000	0.00118
270	0.00000	0.00000	0.00367	0.00000	0.00000	0.01930	0.00002	0.00000	0.00110
280	0.00000	0.00000	0.00352	0.00000	0.00000	0.01862	0.00002	0.00000	0.00103
290	0.00000	0.00000	0.00337	0.00000	0.00000	0.01798	0.00001	0.00000	0.00097
300	0.00000	0.00000	0.00324	0.00000	0.00000	0.01738	0.00001	0.00000	0.00091

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation					
	Zpg*			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.01393	0.00098	0.09648	0.04051	0.00712	0.14958
2	0.00446	0.00022	0.04351	0.01576	0.00089	0.12002
3	0.00213	0.00008	0.02561	0.00848	0.00020	0.10841
4	0.00122	0.00004	0.01708	0.00529	0.00006	0.10152
5	0.00078	0.00002	0.01227	0.00361	0.00002	0.09673
6	0.00053	0.00001	0.00926	0.00261	0.00001	0.09310
7	0.00038	0.00001	0.00724	0.00197	0.00000	0.09020
8	0.00028	0.00001	0.00582	0.00153	0.00000	0.08780
9	0.00022	0.00000	0.00478	0.00122	0.00000	0.08577
10	**0.00017**	**0.00000**	**0.00400**	**0.00099**	**0.00000**	**0.08400**
11	0.00014	0.00000	0.00339	0.00082	0.00000	0.08245
12	0.00011	0.00000	0.00291	0.00069	0.00000	0.08107
13	0.00009	0.00000	0.00252	0.00059	0.00000	0.07982
14	0.00008	0.00000	0.00220	0.00050	0.00000	0.07869
15	0.00007	0.00000	0.00194	0.00044	0.00000	0.07766
16	0.00006	0.00000	0.00172	0.00038	0.00000	0.07670
17	0.00005	0.00000	0.00154	0.00033	0.00000	0.07582
18	0.00004	0.00000	0.00138	0.00030	0.00000	0.07500
19	0.00004	0.00000	0.00125	0.00026	0.00000	0.07424
20	0.00003	0.00000	0.00113	0.00023	0.00000	0.07352
21	0.00003	0.00000	0.00103	0.00021	0.00000	0.07285
22	0.00003	0.00000	0.00094	0.00019	0.00000	0.07221
23	0.00002	0.00000	0.00086	0.00017	0.00000	0.07161
24	0.00002	0.00000	0.00079	0.00016	0.00000	0.07104
25	0.00002	0.00000	0.00073	0.00014	0.00000	0.07050
26	0.00002	0.00000	0.00068	0.00013	0.00000	0.06998
27	0.00001	0.00000	0.00063	0.00012	0.00000	0.06949
28	0.00001	0.00000	0.00058	0.00011	0.00000	0.06901
29	0.00001	0.00000	0.00054	0.00010	0.00000	0.06856
30	0.00001	0.00000	0.00051	0.00009	0.00000	0.06813
31	0.00001	0.00000	0.00047	0.00009	0.00000	0.06771
32	0.00001	0.00000	0.00044	0.00008	0.00000	0.06731
33	0.00001	0.00000	0.00042	0.00008	0.00000	0.06693
34	0.00001	0.00000	0.00039	0.00007	0.00000	0.06656
35	0.00001	0.00000	0.00037	0.00007	0.00000	0.06620

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation					
	Zpg*			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00001	0.00000	0.00035	0.00006	0.00000	0.06585
37	0.00001	0.00000	0.00033	0.00006	0.00000	0.06551
38	0.00001	0.00000	0.00031	0.00005	0.00000	0.06519
39	0.00001	0.00000	0.00029	0.00005	0.00000	0.06488
40	0.00001	0.00000	0.00028	0.00005	0.00000	0.06457
41	0.00000	0.00000	0.00026	0.00004	0.00000	0.06427
42	0.00000	0.00000	0.00025	0.00004	0.00000	0.06399
43	0.00000	0.00000	0.00024	0.00004	0.00000	0.06371
44	0.00000	0.00000	0.00023	0.00004	0.00000	0.06344
45	0.00000	0.00000	0.00022	0.00004	0.00000	0.06317
46	0.00000	0.00000	0.00021	0.00003	0.00000	0.06291
47	0.00000	0.00000	0.00020	0.00003	0.00000	0.06266
48	0.00000	0.00000	0.00019	0.00003	0.00000	0.06242
49	0.00000	0.00000	0.00018	0.00003	0.00000	0.06218
50	0.00000	0.00000	0.00017	0.00003	0.00000	0.06195
55	0.00000	0.00000	0.00014	0.00002	0.00000	0.06086
60	0.00000	0.00000	0.00011	0.00002	0.00000	0.05988
65	0.00000	0.00000	0.00010	0.00001	0.00000	0.05900
70	0.00000	0.00000	0.00008	0.00001	0.00000	0.05820
75	0.00000	0.00000	0.00007	0.00001	0.00000	0.05746
80	0.00000	0.00000	0.00006	0.00001	0.00000	0.05677
85	0.00000	0.00000	0.00005	0.00001	0.00000	0.05614
90	0.00000	0.00000	0.00005	0.00001	0.00000	0.05554
95	0.00000	0.00000	0.00004	0.00001	0.00000	0.05499
100	0.00000	0.00000	0.00004	0.00000	0.00000	0.05447
110	0.00000	0.00000	0.00003	0.00000	0.00000	0.05351
120	0.00000	0.00000	0.00002	0.00000	0.00000	0.05265
130	0.00000	0.00000	0.00002	0.00000	0.00000	0.05187
140	0.00000	0.00000	0.00002	0.00000	0.00000	0.05116
150	0.00000	0.00000	0.00001	0.00000	0.00000	0.05051
160	0.00000	0.00000	0.00001	0.00000	0.00000	0.04990
170	0.00000	0.00000	0.00001	0.00000	0.00000	0.04934
180	0.00000	0.00000	0.00001	0.00000	0.00000	0.04882
190	0.00000	0.00000	0.00001	0.00000	0.00000	0.04833
200	0.00000	0.00000	0.00001	0.00000	0.00000	0.04787

Appendix 3. Probability of arsenic exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Arsenic, in micrograms per liter	Bedrock unit abbreviation					
	Zpg*			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00000	0.00000	0.00001	0.00000	0.00000	0.04743
220	0.00000	0.00000	0.00000	0.00000	0.00000	0.04702
230	0.00000	0.00000	0.00000	0.00000	0.00000	0.04663
240	0.00000	0.00000	0.00000	0.00000	0.00000	0.04626
250	0.00000	0.00000	0.00000	0.00000	0.00000	0.04591
260	0.00000	0.00000	0.00000	0.00000	0.00000	0.04557
270	0.00000	0.00000	0.00000	0.00000	0.00000	0.04525
280	0.00000	0.00000	0.00000	0.00000	0.00000	0.04494
290	0.00000	0.00000	0.00000	0.00000	0.00000	0.04464
300	0.00000	0.00000	0.00000	0.00000	0.00000	0.04436

Appendix 4. Arsenic Log-Normal Fit Statistics by Bedrock Unit

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Grouped bedrock units with elevated-arsenic concentration				
Censoring information	**Count**			
Uncensored value	142			
Left censored value	13			
Parameter estimates				
Parameter	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**
Location	0.842088	0.160891	0.526746	1.15743
Scale	1.98346	0.122107	1.75801	2.23782
Log-likelihood	-484.214			
Goodness-of-fit				
Anderson-Darling (adjusted)	0.431			
Correlation coefficient	0.999			
Characteristics of distribution				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**
Mean	16.5957	4.65715	9.57473	28.7649
Standard deviation	117.486	59.1549	43.7925	315.189
Median	2.32121	0.373462	1.69341	3.18174
First quartile (Q1)	0.609123	0.113368	0.422943	0.877259
Third quartile (Q3)	8.84551	1.54983	6.27455	12.4699
Interquartile range (IQR)	8.23639	1.48626	5.78278	11.7311

Bedrock unit abbreviation				
Ops*				
Censoring information	**Count**			
Uncensored value	2			
Left censored value	8			
Parameter estimates				
Parameter	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**
Location	-3.21928	0.787011	-4.7618	-1.67677
Scale	1.78003	0.0901298	1.61186	1.96574
Log-likelihood	-4.305			
Goodness-of-fit				
Anderson-Darling (adjusted)	2.245			
Correlation coefficient	1			
Characteristics of distribution				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**
Mean	0.194946	0.152905	0.041906	0.906885
Standard deviation	0.93028	0.759049	0.18797	4.60404
Median	0.0399836	0.0314676	0.0085502	0.186977
First quartile (Q1)	0.0120355	0.0095863	0.0025262	0.0573391
Third quartile (Q3)	0.132832	0.103893	0.0286776	0.615262
Interquartile range (IQR)	0.120796	0.0944301	0.0261001	0.559067

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
OZf					OZm				
Censoring information		Count			Censoring information		Count		
Uncensored value		7			Uncensored value		4		
Left censored value		1			Left censored value		6		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					Parameter estimates				
Parameter	Estimate	Standard error	95% normal CI		Parameter	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Location	0.203812	0.537881	-0.850415	1.25804	Location	-3.14197	2.2943	-7.63872	1.35477
Scale	1.46776	0.444717	0.810489	2.65803	Scale	4.40671	2.19624	1.65915	11.7042
Log-likelihood		-19.146			Log-likelihood		-20.355		
Goodness-of-fit					Goodness-of-fit				
Anderson-Darling (adjusted)		3.106			Anderson-Darling (adjusted)		2.122		
Correlation coefficient		0.922			Correlation coefficient		0.956		
Characteristics of distribution					Characteristics of distribution				
Descriptor	Estimate	Standard error	95% normal CI		Descriptor	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Mean	3.60011	2.6815	0.836197	15.4997	Mean	711.633	5.84×10^3	0.0000725	6.99×10^9
Standard deviation	9.93912	13.636	0.675371	146.269	Standard deviation	1.17×10^7	2.09×10^8	0	1.68×10^{22}
Median	1.22607	0.659479	0.427238	3.51852	Median	0.0431974	0.0991078	0.0004814	3.87586
First quartile (Q1)	0.455585	0.306663	0.121789	1.70424	First quartile (Q1)	0.0022111	0.0077461	0.0000023	2.1211
Third quartile (Q3)	3.29959	1.82372	1.11684	9.7483	Third quartile (Q3)	0.843922	1.3722	0.0348552	20.4332
Interquartile range (IQR)	2.84401	1.67949	0.89385	9.04891	Interquartile range (IQR)	0.841711	1.36804	0.0348095	20.353

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
OZn					OZnb				
Censoring information	Count				Censoring information	Count			
Uncensored value	19				Uncensored value	17			
Left censored value	12				Left censored value	3			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					Parameter estimates				
Parameter	Estimate	Standard error	95% normal CI		Parameter	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Location	-1.58309	0.352176	-2.27334	-0.892837	Location	0.779948	0.531552	-0.261874	1.82177
Scale	1.6106	0.349339	1.05283	2.46384	Scale	2.31159	0.437248	1.59552	3.34903
Log-likelihood	-33.677				Log-likelihood	-67.412			
Goodness-of-fit					Goodness-of-fit				
Anderson-Darling (adjusted)	3.307				Anderson-Darling (adjusted)	1.281			
Correlation coefficient	0.981				Correlation coefficient	0.98			
Characteristics of distribution					Characteristics of distribution				
Descriptor	Estimate	Standard error	95% normal CI		Descriptor	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Mean	0.751202	0.37721	0.280759	2.00993	Mean	31.5531	33.5261	3.93202	253.203
Standard deviation	2.64349	2.77567	0.337609	20.6986	Standard deviation	455.321	914.887	8.87111	2.34×10^4
Median	0.20534	0.0723157	0.102968	0.409492	Median	2.18136	1.1595	0.769608	6.18279
First quartile (Q1)	0.0692924	0.035228	0.0255822	0.187687	First quartile (Q1)	0.458775	0.297545	0.128689	1.63553
Third quartile (Q3)	0.608499	0.193027	0.326771	1.13312	Third quartile (Q3)	10.3718	5.85262	3.43193	31.3452
Interquartile range (IQR)	0.539207	0.180896	0.279377	1.04069	Interquartile range (IQR)	9.91304	5.69917	3.21246	30.5898

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Sgr					**SOagr**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	7				Uncensored value	7			
Left censored value	0				Left censored value	5			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.0870687	0.221555	-0.521308	0.347171	Location	-0.996819	0.724544	-2.4169	0.423261
Scale	0.505699	0.101615	0.341076	0.749778	Scale	2.22697	0.632122	1.27674	3.88443
Log-likelihood	-9.715				Log-likelihood	-24.772			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	3.111				Anderson-Darling (adjusted)	1.726			
Correlation coefficient	0.954				Correlation coefficient	0.947			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	1.04164	0.20888	0.703116	1.54315	Mean	4.40564	5.98493	0.307381	63.1452
Standard deviation	0.562298	0.142746	0.341884	0.924815	Standard deviation	52.4085	140.438	0.274442	1.00 × 10^4
Median	0.916614	0.20308	0.593743	1.41506	Median	0.369052	0.267394	0.0891978	1.52693
First quartile (Q1)	0.651709	0.171367	0.389252	1.09113	First quartile (Q1)	0.0821762	0.078262	0.0127084	0.531378
Third quartile (Q3)	1.2892	0.252714	0.877936	1.89311	Third quartile (Q3)	1.6574	1.17954	0.410814	6.68669
Interquartile range (IQR)	0.637489	0.136533	0.418955	0.970013	Interquartile range (IQR)	1.57523	1.14191	0.380445	6.5222

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Spsq*					**Spss**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	4				Uncensored value	5			
Left censored value	5				Left censored value	2			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-2.41045	0.846842	-4.07023	-0.750667	Location	-0.867381	0.508521	-1.86406	0.129302
Scale	1.57953	0.495804	0.853772	2.92223	Scale	1.18838	0.332903	0.686285	2.0578
Log-likelihood	-10.109				Log-likelihood	-10.976			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	2.121				Anderson-Darling (adjusted)	2.799			
Correlation coefficient	0.966				Correlation coefficient	0.982			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.312551	0.199818	0.0892766	1.09422	Mean	0.851069	0.428686	0.317112	2.28411
Standard deviation	1.04229	1.26353	0.0968518	11.2168	Standard deviation	1.4997	1.27936	0.281753	7.98256
Median	0.0897751	0.0760253	0.0170735	0.472051	Median	0.42005	0.213604	0.155041	1.13803
First quartile (Q1)	0.0309363	0.0342062	0.0035424	0.270172	First quartile (Q1)	0.188449	0.119276	0.0545049	0.651556
Third quartile (Q3)	0.260522	0.171901	0.0714813	0.9495	Third quartile (Q3)	0.936287	0.436567	0.375418	2.33509
Interquartile range (IQR)	0.229585	0.144786	0.0667025	0.790216	Interquartile range (IQR)	0.747838	0.362431	0.289256	1.93345

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Ssqd					**SZtb**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		11			Uncensored value		29		
Left censored value		0			Left censored value		4		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	0.412493	0.343881	-0.261502	1.08649	Location	-0.203752	0.250689	-0.695093	0.287588
Scale	1.1237	0.320478	0.642518	1.96522	Scale	1.40051	0.187371	1.07747	1.8204
Log-likelihood		-21.008			Log-likelihood		-62.075		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		2.392			Anderson-Darling (adjusted)		0.892		
Correlation coefficient		0.951			Correlation coefficient		0.992		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	2.8401	1.28763	1.16794	6.90631	Mean	2.17486	0.715688	1.1411	4.14514
Standard deviation	4.52184	3.94286	0.818658	24.9763	Standard deviation	5.3757	3.10934	1.7302	16.7023
Median	1.51058	0.51946	0.769894	2.96385	Median	0.815664	0.204478	0.499028	1.33321
First quartile (Q1)	0.707917	0.308919	0.30098	1.66505	First quartile (Q1)	0.317149	0.0951949	0.176104	0.571161
Third quartile (Q3)	3.22333	1.20405	1.55005	6.70291	Third quartile (Q3)	2.09778	0.545174	1.26051	3.49117
Interquartile range (IQR)	2.51541	1.10396	1.06423	5.94541	Interquartile range (IQR)	1.78063	0.49387	1.03392	3.06662

Appendix 4. Arsenic log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Zpg*					**Zsg**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	2				Uncensored value	7			
Left censored value	9				Left censored value	16			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-3.66411	0.771435	-5.17609	-2.15212	Location	-2.98176	0.999948	-4.94162	-1.0219
Scale	1.66617	0.100537	1.48032	1.87534	Scale	1.70893	0.748103	0.724607	4.03039
Log-likelihood	-3.006				Log-likelihood	-14.871			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	2.214				Anderson-Darling (adjusted)	2.733			
Correlation coefficient	1				Correlation coefficient	0.982			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.102689	0.0779394	0.0231993	0.454541	Mean	0.218376	0.130661	0.0675934	0.705514
Standard deviation	0.398461	0.313134	0.0854009	1.85913	Standard deviation	0.914828	1.64495	0.0269649	31.037
Median	0.0256271	0.0197696	0.0056501	0.116237	Median	0.0507034	0.0507008	0.007143	0.35991
First quartile (Q1)	0.0083298	0.0065524	0.0017826	0.0389236	First quartile (Q1)	0.016012	0.0234942	0.0009026	0.284057
Third quartile (Q3)	0.0788433	0.0600783	0.0177073	0.351056	Third quartile (Q3)	0.160557	0.0958063	0.049855	0.517073
Interquartile range (IQR)	0.0705135	0.0536348	0.0158789	0.313129	Interquartile range (IQR)	0.144545	0.0768037	0.0510177	0.409532

Appendix 5. Probability of Uranium Exceeding a Given Concentration by Bedrock Unit

Appendix 5. Probability of uranium exceeding a given concentration by bedrock unit.

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Dcgr			Dfgr			Dl		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.95614	0.51366	0.99964	0.64549	0.32667	0.88405	0.15706	0.03907	0.40068
2	0.88401	0.43605	0.99464	0.53055	0.24734	0.79848	0.06707	0.00759	0.28505
3	0.81477	0.38671	0.98120	0.46145	0.20378	0.73716	0.03710	0.00226	0.23244
4	0.75269	0.34946	0.96018	0.41300	0.17473	0.69003	0.02333	0.00085	0.20043
5	0.69779	0.31902	0.93403	0.37627	0.15347	0.65213	0.01588	0.00037	0.17825
6	0.64925	0.29304	0.90509	0.34705	0.13703	0.62065	0.01140	0.00018	0.16167
7	0.60617	0.27025	0.87509	0.32303	0.12384	0.59389	0.00852	0.00010	0.14867
8	0.56776	0.24991	0.84521	0.30281	0.11296	0.57073	0.00656	0.00005	0.13812
9	0.53332	0.23154	0.81621	0.28545	0.10381	0.55040	0.00517	0.00003	0.12932
10	0.50229	0.21481	0.78853	0.27033	0.09599	0.53235	0.00416	0.00002	0.12185
11	0.47420	0.19950	0.76239	0.25702	0.08921	0.51615	0.00340	0.00001	0.11540
12	0.44867	0.18543	0.73789	0.24516	0.08328	0.50151	0.00282	0.00001	0.10976
13	0.42537	0.17247	0.71502	0.23452	0.07804	0.48817	0.00237	0.00001	0.10476
14	0.40402	0.16051	0.69373	0.22490	0.07337	0.47595	0.00201	0.00000	0.10031
15	0.38440	0.14947	0.67395	0.21615	0.06918	0.46470	0.00172	0.00000	0.09631
16	0.36631	0.13925	0.65557	0.20815	0.06541	0.45429	0.00148	0.00000	0.09268
17	0.34958	0.12980	0.63849	0.20079	0.06199	0.44461	0.00129	0.00000	0.08937
18	0.33407	0.12106	0.62261	0.19400	0.05887	0.43558	0.00112	0.00000	0.08635
19	0.31966	0.11296	0.60782	0.18771	0.05602	0.42713	0.00099	0.00000	0.08356
20	0.30623	0.10545	0.59404	0.18186	0.05341	0.41920	0.00087	0.00000	0.08099
21	0.29369	0.09850	0.58116	0.17640	0.05100	0.41173	0.00078	0.00000	0.07860
22	0.28197	0.09206	0.56912	0.17129	0.04877	0.40469	0.00069	0.00000	0.07638
23	0.27098	0.08609	0.55784	0.16650	0.04670	0.39802	0.00062	0.00000	0.07431
24	0.26066	0.08055	0.54726	0.16199	0.04478	0.39170	0.00056	0.00000	0.07236
25	0.25095	0.07541	0.53731	0.15775	0.04299	0.38569	0.00050	0.00000	0.07054
26	0.24181	0.07064	0.52794	0.15374	0.04132	0.37997	0.00046	0.00000	0.06882
27	0.23319	0.06621	0.51910	0.14994	0.03976	0.37453	0.00042	0.00000	0.06721
28	0.22505	0.06209	0.51074	0.14635	0.03830	0.36932	0.00038	0.00000	0.06568
29	0.21735	0.05827	0.50284	0.14293	0.03692	0.36435	0.00035	0.00000	0.06423
30	**0.21005**	**0.05471**	**0.49534**	**0.13968**	**0.03562**	**0.35958**	**0.00032**	**0.00000**	**0.06285**
31	0.20313	0.05140	0.48822	0.13659	0.03440	0.35501	0.00029	0.00000	0.06155
32	0.19657	0.04832	0.48146	0.13364	0.03325	0.35062	0.00027	0.00000	0.06031
33	0.19033	0.04545	0.47502	0.13082	0.03216	0.34640	0.00025	0.00000	0.05912
34	0.18439	0.04277	0.46887	0.12813	0.03113	0.34234	0.00023	0.00000	0.05799
35	0.17874	0.04028	0.46301	0.12555	0.03015	0.33843	0.00021	0.00000	0.05691

Appendix 5. Probability of uranium exceeding a given concentration by bedrock unit. —Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micro-grams per liter	Bedrock unit abbreviation								
	Dcgr			Dfgr			Dl		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.17335	0.03795	0.45740	0.12308	0.02922	0.33466	0.00020	0.00000	0.05588
37	0.16821	0.03577	0.45204	0.12071	0.02834	0.33103	0.00018	0.00000	0.05489
38	0.16331	0.03374	0.44690	0.11843	0.02750	0.32751	0.00017	0.00000	0.05394
39	0.15862	0.03185	0.44196	0.11624	0.02670	0.32411	0.00016	0.00000	0.05302
40	0.15413	0.03007	0.43723	0.11414	0.02593	0.32082	0.00015	0.00000	0.05215
41	0.14984	0.02841	0.43267	0.11211	0.02521	0.31764	0.00014	0.00000	0.05130
42	0.14573	0.02686	0.42829	0.11016	0.02451	0.31455	0.00013	0.00000	0.05049
43	0.14179	0.02540	0.42407	0.10828	0.02385	0.31156	0.00012	0.00000	0.04971
44	0.13801	0.02404	0.42001	0.10646	0.02321	0.30866	0.00011	0.00000	0.04896
45	0.13438	0.02275	0.41608	0.10470	0.02260	0.30584	0.00011	0.00000	0.04823
46	0.13090	0.02155	0.41229	0.10301	0.02202	0.30310	0.00010	0.00000	0.04752
47	0.12755	0.02043	0.40863	0.10137	0.02146	0.30044	0.00009	0.00000	0.04684
48	0.12433	0.01937	0.40508	0.09978	0.02093	0.29785	0.00009	0.00000	0.04619
49	0.12123	0.01837	0.40165	0.09824	0.02041	0.29533	0.00008	0.00000	0.04555
50	0.11825	0.01743	0.39833	0.09676	0.01992	0.29287	0.00008	0.00000	0.04493
55	0.10488	0.01351	0.38316	0.08995	0.01770	0.28149	0.00006	0.00000	0.04212
60	0.09366	0.01058	0.36997	0.08406	0.01586	0.27140	0.00005	0.00000	0.03968
65	0.08415	0.00836	0.35838	0.07890	0.01430	0.26236	0.00004	0.00000	0.03754
70	0.07600	0.00667	0.34806	0.07434	0.01297	0.25420	0.00003	0.00000	0.03565
75	0.06897	0.00537	0.33880	0.07028	0.01183	0.24678	0.00002	0.00000	0.03397
80	0.06286	0.00435	0.33042	0.06664	0.01083	0.23999	0.00002	0.00000	0.03245
85	0.05751	0.00355	0.32278	0.06335	0.00996	0.23375	0.00002	0.00000	0.03108
90	0.05281	0.00292	0.31578	0.06037	0.00919	0.22798	0.00001	0.00000	0.02983
95	0.04864	0.00241	0.30932	0.05765	0.00851	0.22263	0.00001	0.00000	0.02869
100	0.04493	0.00201	0.30335	0.05516	0.00790	0.21764	0.00001	0.00000	0.02765
110	0.03865	0.00141	0.29260	0.05076	0.00687	0.20862	0.00001	0.00000	0.02579
120	0.03356	0.00101	0.28316	0.04699	0.00603	0.20064	0.00001	0.00000	0.02419
130	0.02938	0.00073	0.27479	0.04373	0.00534	0.19352	0.00000	0.00000	0.02279
140	0.02590	0.00054	0.26728	0.04087	0.00476	0.18712	0.00000	0.00000	0.02156
150	0.02298	0.00040	0.26048	0.03835	0.00427	0.18131	0.00000	0.00000	0.02047
160	0.02050	0.00031	0.25429	0.03610	0.00385	0.17601	0.00000	0.00000	0.01949
170	0.01839	0.00024	0.24862	0.03409	0.00349	0.17115	0.00000	0.00000	0.01860
180	0.01656	0.00018	0.24339	0.03229	0.00318	0.16666	0.00000	0.00000	0.01780
190	0.01498	0.00014	0.23855	0.03065	0.00290	0.16251	0.00000	0.00000	0.01708
200	0.01361	0.00011	0.23404	0.02916	0.00266	0.15865	0.00000	0.00000	0.01641

Appendix 5. Probability of uranium exceeding a given concentration by bedrock unit. —Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Dcgr			Dfgr			Dl		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.01240	0.00009	0.22983	0.02780	0.00245	0.15505	0.00000	0.00000	0.01579
220	0.01134	0.00007	0.22589	0.02655	0.00226	0.15168	0.00000	0.00000	0.01523
230	0.01040	0.00006	0.22219	0.02541	0.00210	0.14852	0.00000	0.00000	0.01470
240	0.00956	0.00005	0.21869	0.02435	0.00195	0.14554	0.00000	0.00000	0.01422
250	0.00881	0.00004	0.21539	0.02337	0.00181	0.14273	0.00000	0.00000	0.01376
260	0.00815	0.00003	0.21227	0.02245	0.00169	0.14007	0.00000	0.00000	0.01334
270	0.00755	0.00003	0.20930	0.02161	0.00158	0.13755	0.00000	0.00000	0.01294
280	0.00700	0.00002	0.20648	0.02082	0.00148	0.13516	0.00000	0.00000	0.01257
290	0.00651	0.00002	0.20379	0.02007	0.00139	0.13289	0.00000	0.00000	0.01222
300	0.00607	0.00002	0.20122	0.01938	0.00130	0.13073	0.00000	0.00000	0.01189

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	DSw			Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.27948	0.09368	0.55948	0.0035097	0.0002758	0.0263434	0.22587	0.07024	0.48763
2	0.14055	0.02225	0.44187	0.0009592	0.0000546	0.0097475	0.08718	0.01214	0.32133
3	0.08590	0.00696	0.39223	0.0004182	0.0000196	0.005111	0.04339	0.00294	0.25130
4	0.05806	0.00263	0.36239	0.0002247	0.0000091	0.0031409	0.02476	0.00089	0.21056
5	0.04181	0.00114	0.34152	0.0001362	0.0000049	0.0021176	0.01542	0.00032	0.18314
6	0.03145	0.00054	0.32567	0.0000894	0.0000029	0.0015181	0.01021	0.00013	0.16310
7	0.02444	0.00028	0.31299	0.0000621	0.0000019	0.0011371	0.00708	0.00006	0.14764
8	0.01948	0.00015	0.30248	0.000045	0.0000013	0.0008804	0.00509	0.00003	0.13527
9	0.01584	0.00009	0.29355	0.0000337	0.0000009	0.0006995	0.00376	0.00001	0.12510
10	0.01309	0.00005	0.28580	0.000026	0.0000007	0.0005675	0.00285	0.00001	0.11655
11	0.01097	0.00003	0.27898	0.0000204	0.0000005	0.0004683	0.00220	0.00000	0.10924
12	0.00930	0.00002	0.27290	0.0000163	0.0000004	0.0003921	0.00173	0.00000	0.10290
13	0.00797	0.00001	0.26742	0.0000133	0.0000003	0.0003324	0.00138	0.00000	0.09735
14	0.00689	0.00001	0.26245	0.000011	0.0000002	0.0002847	0.00111	0.00000	0.09243
15	0.00600	0.00001	0.25790	0.0000091	0.0000002	0.0002462	0.00091	0.00000	0.08804
16	0.00526	0.00000	0.25372	0.0000077	0.0000001	0.0002146	0.00075	0.00000	0.08409
17	0.00464	0.00000	0.24984	0.0000066	0.0000001	0.0001884	0.00062	0.00000	0.08052
18	0.00412	0.00000	0.24624	0.0000056	0.0000001	0.0001665	0.00052	0.00000	0.07727
19	0.00368	0.00000	0.24288	0.0000049	0.0000001	0.000148	0.00044	0.00000	0.07429
20	0.00329	0.00000	0.23973	0.0000042	0.0000001	0.0001322	0.00038	0.00000	0.07156
21	0.00296	0.00000	0.23676	0.0000037	0.0000001	0.0001187	0.00032	0.00000	0.06904
22	0.00268	0.00000	0.23397	0.0000033	0.0000001	0.000107	0.00028	0.00000	0.06670
23	0.00243	0.00000	0.23132	0.0000029	0.0000000	0.0000969	0.00024	0.00000	0.06453
24	0.00221	0.00000	0.22882	0.0000026	0.0000000	0.0000881	0.00021	0.00000	0.06251
25	0.00202	0.00000	0.22643	0.0000023	0.0000000	0.0000803	0.00018	0.00000	0.06062
26	0.00184	0.00000	0.22417	0.000002	0.0000000	0.0000734	0.00016	0.00000	0.05885
27	0.00169	0.00000	0.22200	0.0000018	0.0000000	0.0000674	0.00014	0.00000	0.05719
28	0.00156	0.00000	0.21993	0.0000017	0.0000000	0.000062	0.00012	0.00000	0.05563
29	0.00143	0.00000	0.21795	0.0000015	0.0000000	0.0000572	0.00011	0.00000	0.05416
30	**0.00133**	**0.00000**	**0.21606**	**0.0000014**	0.0000000	**0.0000528**	**0.00010**	**0.00000**	**0.05276**
31	0.00123	0.00000	0.21423	0.0000012	0.0000000	0.000049	0.00009	0.00000	0.05145
32	0.00114	0.00000	0.21248	0.0000011	0.0000000	0.0000455	0.00008	0.00000	0.05020
33	0.00106	0.00000	0.21079	0.000001	0.0000000	0.0000423	0.00007	0.00000	0.04901
34	0.00099	0.00000	0.20917	0.0000009	0.0000000	0.0000394	0.00006	0.00000	0.04788
35	0.00092	0.00000	0.20760	0.0000009	0.0000000	0.0000368	0.00006	0.00000	0.04681

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	DSw			Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00086	0.00000	0.20608	0.0000008	0.0000001	0.0000344	0.00005	0.00000	0.04578
37	0.00080	0.00000	0.20462	0.0000007	0.0000001	0.0000323	0.00005	0.00000	0.04480
38	0.00075	0.00000	0.20320	0.0000007	0.0000000	0.0000303	0.00004	0.00000	0.04387
39	0.00071	0.00000	0.20183	0.0000006	0.0000000	0.0000285	0.00004	0.00000	0.04297
40	0.00066	0.00000	0.20050	0.0000006	0.0000000	0.0000268	0.00004	0.00000	0.04211
41	0.00062	0.00000	0.19921	0.0000005	0.0000000	0.0000252	0.00003	0.00000	0.04129
42	0.00059	0.00000	0.19796	0.0000005	0.0000000	0.0000238	0.00003	0.00000	0.04050
43	0.00055	0.00000	0.19674	0.0000005	0.0000000	0.0000225	0.00003	0.00000	0.03974
44	0.00052	0.00000	0.19555	0.0000004	0.0000000	0.0000213	0.00003	0.00000	0.03901
45	0.00049	0.00000	0.19440	0.0000004	0.0000000	0.0000201	0.00002	0.00000	0.03831
46	0.00047	0.00000	0.19328	0.0000004	0.0000001	0.0000191	0.00002	0.00000	0.03764
47	0.00044	0.00000	0.19219	0.0000004	0.0000001	0.0000181	0.00002	0.00000	0.03699
48	0.00042	0.00000	0.19113	0.0000003	0.0000000	0.0000172	0.00002	0.00000	0.03636
49	0.00040	0.00000	0.19009	0.0000003	0.0000000	0.0000163	0.00002	0.00000	0.03575
50	0.00038	0.00000	0.18908	0.0000003	0.0000000	0.0000155	0.00002	0.00000	0.03516
55	0.00029	0.00000	0.18436	0.0000002	0.0000000	0.0000123	0.00001	0.00000	0.03251
60	0.00023	0.00000	0.18014	0.0000002	0.0000000	0.0000099	0.00001	0.00000	0.03024
65	0.00019	0.00000	0.17633	0.0000001	0.0000000	0.000008	0.00001	0.00000	0.02827
70	0.00015	0.00000	0.17286	0.0000001	0.0000000	0.0000067	0.00000	0.00000	0.02654
75	0.00013	0.00000	0.16967	0.0000001	0.0000000	0.0000056	0.00000	0.00000	0.02502
80	0.00011	0.00000	0.16673	0.0000001	0.0000001	0.0000047	0.00000	0.00000	0.02367
85	0.00009	0.00000	0.16401	0.0000001	0.0000001	0.000004	0.00000	0.00000	0.02245
90	0.00008	0.00000	0.16148	0.0000000	0.0000000	0.0000035	0.00000	0.00000	0.02136
95	0.00007	0.00000	0.15911	0.0000000	0.0000000	0.000003	0.00000	0.00000	0.02036
100	0.00006	0.00000	0.15689	0.0000000	0.0000000	0.0000026	0.00000	0.00000	0.01946
110	0.00004	0.00000	0.15282	0.0000000	0.0000000	0.000002	0.00000	0.00000	0.01787
120	0.00003	0.00000	0.14918	0.0000000	0.0000000	0.0000016	0.00000	0.00000	0.01652
130	0.00003	0.00000	0.14590	0.0000000	0.0000000	0.0000013	0.00000	0.00000	0.01536
140	0.00002	0.00000	0.14290	0.0000000	0.0000000	0.000001	0.00000	0.00000	0.01434
150	0.00002	0.00000	0.14016	0.0000000	0.0000000	0.0000009	0.00000	0.00000	0.01346
160	0.00001	0.00000	0.13763	0.0000001	0.0000001	0.0000007	0.00000	0.00000	0.01267
170	0.00001	0.00000	0.13529	0.0000001	0.0000001	0.0000006	0.00000	0.00000	0.01197
180	0.00001	0.00000	0.13311	0.0000000	0.0000000	0.0000005	0.00000	0.00000	0.01133
190	0.00001	0.00000	0.13107	0.0000000	0.0000000	0.0000004	0.00000	0.00000	0.01077
200	0.00001	0.00000	0.12916	0.0000000	0.0000000	0.0000004	0.00000	0.00000	0.01025

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	DSw			Ops*			OZf		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00001	0.00000	0.12737	0.0000000	0.0000000	0.0000003	0.00000	0.00000	0.00978
220	0.00001	0.00000	0.12567	0.0000000	0.0000000	0.0000003	0.00000	0.00000	0.00935
230	0.00000	0.00000	0.12407	0.0000000	0.0000000	0.0000003	0.00000	0.00000	0.00895
240	0.00000	0.00000	0.12255	0.0000000	0.0000000	0.0000002	0.00000	0.00000	0.00859
250	0.00000	0.00000	0.12111	0.0000000	0.0000000	0.0000002	0.00000	0.00000	0.00825
260	0.00000	0.00000	0.11973	0.0000001	0.0000001	0.0000002	0.00000	0.00000	0.00794
270	0.00000	0.00000	0.11842	0.0000001	0.0000001	0.0000002	0.00000	0.00000	0.00764
280	0.00000	0.00000	0.11717	0.0000000	0.0000000	0.0000001	0.00000	0.00000	0.00737
290	0.00000	0.00000	0.11597	0.0000000	0.0000000	0.0000001	0.00000	0.00000	0.00712
300	0.00000	0.00000	0.11482	0.0000000	0.0000000	0.0000001	0.00000	0.00000	0.00688

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.39299	0.18635	0.63622	0.50445	0.36570	0.64266	0.20132	0.09010	0.36931
2	0.28816	0.11589	0.53119	0.31779	0.20138	0.45578	0.12168	0.04290	0.26921
3	0.23368	0.08203	0.47528	0.22434	0.12633	0.35520	0.08700	0.02593	0.21925
4	0.19878	0.06210	0.43859	0.16880	0.08553	0.29148	0.06729	0.01758	0.18780
5	0.17401	0.04905	0.41184	0.13241	0.06099	0.24710	0.05453	0.01276	0.16567
6	0.15529	0.03993	0.39107	0.10700	0.04518	0.21425	0.04559	0.00970	0.14902
7	0.14054	0.03324	0.37425	0.08842	0.03446	0.18887	0.03899	0.00763	0.13592
8	0.12856	0.02816	0.36021	0.07437	0.02691	0.16864	0.03392	0.00616	0.12529
9	0.11860	0.02420	0.34821	0.06346	0.02142	0.15212	0.02991	0.00507	0.11643
10	0.11016	0.02104	0.33778	0.05479	0.01732	0.13836	0.02667	0.00424	0.10892
11	0.10291	0.01847	0.32859	0.04778	0.01420	0.12673	0.02399	0.00360	0.10245
12	0.09659	0.01635	0.32039	0.04202	0.01179	0.11676	0.02175	0.00309	0.09681
13	0.09104	0.01458	0.31301	0.03724	0.00988	0.10813	0.01984	0.00268	0.09183
14	0.08611	0.01308	0.30630	0.03321	0.00836	0.10058	0.01821	0.00235	0.08740
15	0.08171	0.01180	0.30018	0.02979	0.00713	0.09392	0.01679	0.00207	0.08343
16	0.07774	0.01070	0.29454	0.02687	0.00613	0.08800	0.01555	0.00183	0.07985
17	0.07415	0.00975	0.28933	0.02434	0.00530	0.08272	0.01446	0.00164	0.07660
18	0.07088	0.00892	0.28449	0.02214	0.00461	0.07797	0.01349	0.00147	0.07362
19	0.06790	0.00819	0.27998	0.02022	0.00403	0.07367	0.01263	0.00132	0.07090
20	0.06515	0.00754	0.27575	0.01853	0.00354	0.06978	0.01185	0.00120	0.06839
21	0.06262	0.00697	0.27178	0.01703	0.00313	0.06622	0.01115	0.00109	0.06607
22	0.06028	0.00646	0.26805	0.01571	0.00277	0.06297	0.01052	0.00100	0.06392
23	0.05811	0.00600	0.26451	0.01452	0.00247	0.05999	0.00995	0.00091	0.06191
24	0.05609	0.00559	0.26117	0.01346	0.00221	0.05724	0.00942	0.00084	0.06004
25	0.05421	0.00522	0.25800	0.01250	0.00198	0.05470	0.00894	0.00077	0.05829
26	0.05244	0.00488	0.25498	0.01164	0.00178	0.05234	0.00850	0.00071	0.05665
27	0.05079	0.00457	0.25210	0.01086	0.00160	0.05016	0.00809	0.00066	0.05510
28	0.04923	0.00429	0.24935	0.01015	0.00145	0.04812	0.00772	0.00061	0.05364
29	0.04777	0.00404	0.24673	0.00951	0.00132	0.04623	0.00737	0.00057	0.05227
30	**0.04639**	**0.00380**	**0.24421**	**0.00892**	**0.00120**	**0.04445**	**0.00705**	**0.00053**	**0.05097**
31	0.04508	0.00359	0.24180	0.00838	0.00109	0.04279	0.00675	0.00050	0.04973
32	0.04385	0.00339	0.23948	0.00789	0.00100	0.04123	0.00647	0.00046	0.04856
33	0.04268	0.00321	0.23726	0.00743	0.00091	0.03976	0.00621	0.00043	0.04745
34	0.04157	0.00304	0.23511	0.00702	0.00084	0.03838	0.00596	0.00041	0.04639
35	0.04051	0.00288	0.23304	0.00663	0.00077	0.03708	0.00573	0.00038	0.04538

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.03950	0.00274	0.23105	0.00627	0.00071	0.03584	0.00552	0.00036	0.04442
37	0.03855	0.00260	0.22912	0.00594	0.00065	0.03468	0.00532	0.00034	0.04350
38	0.03763	0.00248	0.22726	0.00563	0.00060	0.03358	0.00513	0.00032	0.04262
39	0.03676	0.00236	0.22546	0.00535	0.00056	0.03253	0.00495	0.00030	0.04177
40	0.03592	0.00225	0.22372	0.00508	0.00052	0.03154	0.00478	0.00029	0.04096
41	0.03512	0.00215	0.22202	0.00483	0.00048	0.03060	0.00462	0.00027	0.04019
42	0.03435	0.00205	0.22038	0.00460	0.00045	0.02970	0.00446	0.00026	0.03944
43	0.03362	0.00196	0.21879	0.00439	0.00041	0.02885	0.00432	0.00024	0.03872
44	0.03291	0.00188	0.21725	0.00418	0.00039	0.02803	0.00418	0.00023	0.03803
45	0.03223	0.00180	0.21574	0.00399	0.00036	0.02725	0.00405	0.00022	0.03737
46	0.03158	0.00173	0.21428	0.00382	0.00034	0.02651	0.00393	0.00021	0.03673
47	0.03095	0.00166	0.21286	0.00365	0.00031	0.02580	0.00381	0.00020	0.03611
48	0.03035	0.00159	0.21148	0.00349	0.00029	0.02512	0.00370	0.00019	0.03551
49	0.02977	0.00153	0.21013	0.00334	0.00028	0.02447	0.00359	0.00018	0.03494
50	0.02921	0.00147	0.20881	0.00320	0.00026	0.02385	0.00349	0.00017	0.03438
55	0.02667	0.00121	0.20270	0.00261	0.00019	0.02109	0.00304	0.00014	0.03185
60	0.02453	0.00102	0.19725	0.00216	0.00014	0.01881	0.00268	0.00012	0.02968
65	0.02268	0.00086	0.19234	0.00181	0.00011	0.01691	0.00238	0.00010	0.02780
70	0.02108	0.00074	0.18788	0.00153	0.00009	0.01530	0.00213	0.00008	0.02615
75	0.01967	0.00064	0.18381	0.00131	0.00007	0.01392	0.00192	0.00007	0.02469
80	0.01843	0.00056	0.18006	0.00112	0.00005	0.01273	0.00174	0.00006	0.02338
85	0.01732	0.00049	0.17660	0.00098	0.00004	0.01169	0.00159	0.00005	0.02221
90	0.01633	0.00043	0.17338	0.00085	0.00004	0.01078	0.00145	0.00004	0.02115
95	0.01544	0.00038	0.17039	0.00075	0.00003	0.00998	0.00134	0.00004	0.02019
100	0.01464	0.00034	0.16758	0.00066	0.00002	0.00927	0.00123	0.00003	0.01932
110	0.01323	0.00028	0.16247	0.00052	0.00002	0.00807	0.00106	0.00003	0.01778
120	0.01206	0.00023	0.15791	0.00042	0.00001	0.00709	0.00092	0.00002	0.01647
130	0.01105	0.00019	0.15381	0.00034	0.00001	0.00629	0.00081	0.00002	0.01533
140	0.01019	0.00016	0.15009	0.00028	0.00001	0.00562	0.00072	0.00001	0.01435
150	0.00944	0.00013	0.14669	0.00024	0.00001	0.00505	0.00064	0.00001	0.01348
160	0.00878	0.00011	0.14357	0.00020	0.00000	0.00457	0.00058	0.00001	0.01271
170	0.00820	0.00010	0.14068	0.00017	0.00000	0.00415	0.00052	0.00001	0.01202
180	0.00769	0.00009	0.13800	0.00015	0.00000	0.00380	0.00047	0.00001	0.01140
190	0.00723	0.00008	0.13551	0.00013	0.00000	0.00348	0.00043	0.00001	0.01084
200	0.00681	0.00007	0.13318	0.00011	0.00000	0.00320	0.00039	0.00001	0.01033

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	OZm			OZn			OZnb		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00644	0.00006	0.13099	0.00010	0.00000	0.00296	0.00036	0.00000	0.00987
220	0.00610	0.00005	0.12893	0.00008	0.00000	0.00274	0.00033	0.00000	0.00944
230	0.00579	0.00005	0.12698	0.00007	0.00000	0.00255	0.00031	0.00000	0.00905
240	0.00550	0.00004	0.12514	0.00007	0.00000	0.00238	0.00029	0.00000	0.00869
250	0.00524	0.00004	0.12340	0.00006	0.00000	0.00222	0.00027	0.00000	0.00836
260	0.00500	0.00003	0.12174	0.00005	0.00000	0.00208	0.00025	0.00000	0.00805
270	0.00478	0.00003	0.12016	0.00005	0.00000	0.00195	0.00023	0.00000	0.00776
280	0.00457	0.00003	0.11866	0.00004	0.00000	0.00183	0.00022	0.00000	0.00749
290	0.00438	0.00003	0.11722	0.00004	0.00000	0.00173	0.00021	0.00000	0.00724
300	0.00421	0.00002	0.11585	0.00003	0.00000	0.00163	0.00019	0.00000	0.00700

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Ph			Sacgr			Sagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.47220	0.23247	0.72282	0.69951	0.59142	0.79240	0.57749	0.33202	0.79539
2	0.38398	0.16877	0.64392	0.55401	0.44593	0.65820	0.46876	0.24920	0.69856
3	0.33475	0.13536	0.59782	0.46387	0.35942	0.57089	0.40572	0.20238	0.63909
4	0.30141	0.11388	0.56571	0.40076	0.30036	0.50822	0.36234	0.17092	0.59719
5	0.27663	0.09862	0.54129	0.35345	0.25703	0.46036	0.32983	0.14795	0.56534
6	0.25715	0.08711	0.52173	0.31637	0.22376	0.42223	0.30418	0.13029	0.53991
7	0.24126	0.07806	0.50549	0.28639	0.19737	0.39093	0.28322	0.11624	0.51890
8	0.22794	0.07073	0.49165	0.26155	0.17592	0.36463	0.26564	0.10476	0.50111
9	0.21654	0.06466	0.47963	0.24061	0.15816	0.34213	0.25060	0.09519	0.48574
10	0.20662	0.05954	0.46903	0.22267	0.14321	0.32261	0.23755	0.08710	0.47226
11	0.19789	0.05515	0.45957	0.20712	0.13048	0.30546	0.22606	0.08015	0.46030
12	0.19012	0.05135	0.45104	0.19351	0.11951	0.29025	0.21586	0.07413	0.44956
13	0.18314	0.04803	0.44328	0.18147	0.10997	0.27664	0.20672	0.06885	0.43985
14	0.17682	0.04509	0.43618	0.17076	0.10162	0.26438	0.19846	0.06420	0.43099
15	0.17106	0.04248	0.42963	0.16116	0.09424	0.25325	0.19095	0.06006	0.42286
16	0.16578	0.04013	0.42357	0.15251	0.08768	0.24311	0.18409	0.05637	0.41537
17	0.16092	0.03802	0.41792	0.14466	0.08183	0.23382	0.17778	0.05304	0.40841
18	0.15643	0.03611	0.41265	0.13752	0.07657	0.22526	0.17196	0.05003	0.40194
19	0.15225	0.03437	0.40770	0.13099	0.07183	0.21735	0.16657	0.04730	0.39589
20	0.14836	0.03277	0.40305	0.12499	0.06754	0.21001	0.16156	0.04481	0.39021
21	0.14472	0.03131	0.39866	0.11947	0.06363	0.20319	0.15689	0.04254	0.38487
22	0.14130	0.02996	0.39450	0.11437	0.06007	0.19682	0.15251	0.04045	0.37983
23	0.13809	0.02872	0.39055	0.10964	0.05681	0.19085	0.14841	0.03852	0.37507
24	0.13507	0.02757	0.38680	0.10524	0.05381	0.18526	0.14455	0.03675	0.37054
25	0.13221	0.02649	0.38323	0.10115	0.05106	0.18000	0.14092	0.03510	0.36625
26	0.12950	0.02549	0.37981	0.09733	0.04851	0.17504	0.13748	0.03357	0.36215
27	0.12693	0.02456	0.37655	0.09375	0.04616	0.17036	0.13423	0.03215	0.35825
28	0.12448	0.02369	0.37343	0.09039	0.04397	0.16593	0.13115	0.03082	0.35452
29	0.12216	0.02287	0.37043	0.08724	0.04195	0.16174	0.12822	0.02958	0.35095
30	**0.11994**	**0.02210**	**0.36755**	**0.08428**	**0.04006**	**0.15776**	**0.12543**	**0.02842**	**0.34752**
31	0.11782	0.02137	0.36477	0.08148	0.03829	0.15397	0.12278	0.02734	0.34423
32	0.11580	0.02069	0.36211	0.07884	0.03665	0.15036	0.12025	0.02631	0.34107
33	0.11386	0.02004	0.35953	0.07634	0.03511	0.14693	0.11783	0.02535	0.33803
34	0.11200	0.01943	0.35705	0.07398	0.03366	0.14365	0.11552	0.02445	0.33510
35	0.11021	0.01886	0.35465	0.07174	0.03230	0.14052	0.11330	0.02359	0.33228

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Ph			Sacgr			Sagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.10850	0.01831	0.35233	0.06961	0.03103	0.13752	0.11118	0.02278	0.32955
37	0.10685	0.01779	0.35008	0.06758	0.02983	0.13465	0.10914	0.02202	0.32691
38	0.10526	0.01729	0.34790	0.06566	0.02869	0.13189	0.10719	0.02129	0.32436
39	0.10373	0.01682	0.34579	0.06383	0.02762	0.12925	0.10530	0.02061	0.32189
40	0.10226	0.01637	0.34374	0.06208	0.02661	0.12672	0.10349	0.01995	0.31950
41	0.10083	0.01594	0.34175	0.06041	0.02566	0.12428	0.10175	0.01933	0.31718
42	0.09946	0.01553	0.33981	0.05881	0.02475	0.12193	0.10007	0.01874	0.31493
43	0.09813	0.01514	0.33793	0.05729	0.02389	0.11967	0.09844	0.01818	0.31274
44	0.09684	0.01476	0.33610	0.05583	0.02308	0.11749	0.09688	0.01765	0.31061
45	0.09559	0.01440	0.33432	0.05443	0.02230	0.11539	0.09536	0.01713	0.30855
46	0.09438	0.01406	0.33258	0.05309	0.02156	0.11337	0.09390	0.01665	0.30654
47	0.09321	0.01373	0.33089	0.05180	0.02086	0.11141	0.09248	0.01618	0.30458
48	0.09208	0.01341	0.32924	0.05056	0.02020	0.10952	0.09111	0.01573	0.30267
49	0.09098	0.01311	0.32762	0.04938	0.01956	0.10769	0.08979	0.01531	0.30081
50	0.08991	0.01281	0.32605	0.04823	0.01895	0.10592	0.08850	0.01490	0.29900
55	0.08498	0.01150	0.31870	0.04313	0.01630	0.09786	0.08261	0.01309	0.29056
60	0.08067	0.01041	0.31210	0.03886	0.01415	0.09092	0.07750	0.01160	0.28303
65	0.07685	0.00948	0.30611	0.03524	0.01240	0.08488	0.07301	0.01035	0.27623
70	0.07343	0.00868	0.30064	0.03215	0.01094	0.07957	0.06904	0.00930	0.27004
75	0.07036	0.00799	0.29562	0.02947	0.00972	0.07486	0.06549	0.00841	0.26438
80	0.06757	0.00739	0.29097	0.02713	0.00869	0.07066	0.06230	0.00764	0.25918
85	0.06504	0.00686	0.28666	0.02508	0.00781	0.06688	0.05942	0.00698	0.25435
90	0.06271	0.00639	0.28263	0.02327	0.00705	0.06347	0.05679	0.00639	0.24987
95	0.06058	0.00597	0.27887	0.02165	0.00639	0.06037	0.05440	0.00588	0.24569
100	0.05860	0.00560	0.27532	0.02021	0.00582	0.05754	0.05220	0.00543	0.24177
110	0.05506	0.00496	0.26883	0.01775	0.00487	0.05257	0.04830	0.00467	0.23462
120	0.05199	0.00443	0.26301	0.01573	0.00413	0.04834	0.04495	0.00406	0.22824
130	0.04928	0.00398	0.25773	0.01405	0.00354	0.04471	0.04203	0.00356	0.22249
140	0.04687	0.00361	0.25292	0.01263	0.00306	0.04154	0.03947	0.00315	0.21726
150	0.04471	0.00329	0.24850	0.01143	0.00266	0.03876	0.03721	0.00280	0.21248
160	0.04277	0.00301	0.24441	0.01039	0.00234	0.03630	0.03518	0.00251	0.20809
170	0.04101	0.00277	0.24062	0.00949	0.00207	0.03411	0.03336	0.00226	0.20402
180	0.03940	0.00256	0.23709	0.00871	0.00183	0.03215	0.03172	0.00204	0.20025
190	0.03793	0.00237	0.23378	0.00802	0.00164	0.03038	0.03023	0.00186	0.19672
200	0.03657	0.00221	0.23068	0.00741	0.00147	0.02878	0.02887	0.00169	0.19343

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Ph			Sacgr			Sagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.03532	0.00206	0.22775	0.00687	0.00132	0.02732	0.02762	0.00155	0.19033
220	0.03416	0.00192	0.22499	0.00639	0.00120	0.02599	0.02647	0.00143	0.18741
230	0.03308	0.00180	0.22237	0.00596	0.00109	0.02477	0.02541	0.00131	0.18466
240	0.03207	0.00170	0.21989	0.00557	0.00099	0.02365	0.02443	0.00122	0.18205
250	0.03113	0.00160	0.21753	0.00522	0.00090	0.02262	0.02352	0.00113	0.17958
260	0.03024	0.00151	0.21527	0.00490	0.00083	0.02166	0.02268	0.00105	0.17723
270	0.02941	0.00143	0.21312	0.00460	0.00076	0.02077	0.02188	0.00097	0.17499
280	0.02863	0.00135	0.21107	0.00434	0.00070	0.01994	0.02114	0.00091	0.17285
290	0.02789	0.00128	0.20910	0.00410	0.00065	0.01917	0.02045	0.00085	0.17080
300	0.02719	0.00122	0.20721	0.00387	0.00060	0.01845	0.01980	0.00080	0.16885

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sb			Sbs			Se		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.44502	0.26442	0.63806	0.28874	0.12867	0.50739	0.35132	0.14117	0.62230
2	0.27017	0.13088	0.45922	0.09640	0.02179	0.27875	0.09921	0.01598	0.33459
3	0.18684	0.07521	0.36649	0.04108	0.00484	0.18692	0.03476	0.00195	0.22850
4	0.13866	0.04725	0.30833	0.02030	0.00133	0.13758	0.01425	0.00029	0.17273
5	0.10768	0.03156	0.26777	0.01108	0.00043	0.10695	0.00654	0.00005	0.13793
6	0.08634	0.02205	0.23754	0.00651	0.00016	0.08622	0.00327	0.00001	0.11407
7	0.07090	0.01596	0.21397	0.00403	0.00006	0.07136	0.00175	0.00000	0.09668
8	0.05933	0.01188	0.19497	0.00261	0.00003	0.06025	0.00099	0.00000	0.08345
9	0.05040	0.00904	0.17928	0.00175	0.00001	0.05168	0.00058	0.00000	0.07308
10	0.04335	0.00702	0.16607	0.00121	0.00001	0.04490	0.00036	0.00000	0.06473
11	0.03768	0.00554	0.15476	0.00086	0.00000	0.03943	0.00022	0.00000	0.05789
12	0.03305	0.00443	0.14495	0.00062	0.00000	0.03494	0.00015	0.00000	0.05218
13	0.02921	0.00359	0.13636	0.00046	0.00000	0.03120	0.00010	0.00000	0.04735
14	0.02600	0.00294	0.12876	0.00034	0.00000	0.02804	0.00007	0.00000	0.04323
15	0.02328	0.00243	0.12199	0.00026	0.00000	0.02536	0.00005	0.00000	0.03967
16	0.02095	0.00203	0.11590	0.00020	0.00000	0.02305	0.00003	0.00000	0.03656
17	0.01895	0.00171	0.11041	0.00016	0.00000	0.02105	0.00002	0.00000	0.03384
18	0.01721	0.00145	0.10542	0.00012	0.00000	0.01930	0.00002	0.00000	0.03144
19	0.01570	0.00123	0.10086	0.00010	0.00000	0.01777	0.00001	0.00000	0.02930
20	0.01437	0.00106	0.09668	0.00008	0.00000	0.01641	0.00001	0.00000	0.02738
21	0.01319	0.00091	0.09284	0.00006	0.00000	0.01520	0.00001	0.00000	0.02566
22	0.01215	0.00079	0.08929	0.00005	0.00000	0.01413	0.00001	0.00000	0.02411
23	0.01122	0.00069	0.08600	0.00004	0.00000	0.01316	0.00000	0.00000	0.02271
24	0.01039	0.00060	0.08294	0.00004	0.00000	0.01229	0.00000	0.00000	0.02143
25	0.00965	0.00053	0.08009	0.00003	0.00000	0.01150	0.00000	0.00000	0.02026
26	0.00898	0.00047	0.07742	0.00003	0.00000	0.01079	0.00000	0.00000	0.01919
27	0.00837	0.00041	0.07493	0.00002	0.00000	0.01014	0.00000	0.00000	0.01821
28	0.00782	0.00037	0.07258	0.00002	0.00000	0.00955	0.00000	0.00000	0.01730
29	0.00732	0.00033	0.07038	0.00002	0.00000	0.00901	0.00000	0.00000	0.01647
30	**0.00686**	**0.00029**	**0.06830**	**0.00001**	**0.00000**	**0.00851**	**0.00000**	**0.00000**	**0.01570**
31	0.00644	0.00026	0.06634	0.00001	0.00000	0.00805	0.00000	0.00000	0.01498
32	0.00606	0.00023	0.06448	0.00001	0.00000	0.00763	0.00000	0.00000	0.01431
33	0.00571	0.00021	0.06273	0.00001	0.00000	0.00724	0.00000	0.00000	0.01369
34	0.00539	0.00019	0.06106	0.00001	0.00000	0.00687	0.00000	0.00000	0.01311
35	0.00509	0.00017	0.05947	0.00001	0.00000	0.00654	0.00000	0.00000	0.01257

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sb			Sbs			Se		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00481	0.00016	0.05797	0.00001	0.00000	0.00623	0.00000	0.00000	0.01206
37	0.00456	0.00014	0.05653	0.00001	0.00000	0.00594	0.00000	0.00000	0.01158
38	0.00432	0.00013	0.05516	0.00000	0.00000	0.00566	0.00000	0.00000	0.01113
39	0.00410	0.00012	0.05386	0.00000	0.00000	0.00541	0.00000	0.00000	0.01071
40	0.00389	0.00011	0.05261	0.00000	0.00000	0.00517	0.00000	0.00000	0.01032
41	0.00370	0.00010	0.05141	0.00000	0.00000	0.00495	0.00000	0.00000	0.00994
42	0.00352	0.00009	0.05027	0.00000	0.00000	0.00474	0.00000	0.00000	0.00959
43	0.00336	0.00008	0.04917	0.00000	0.00000	0.00455	0.00000	0.00000	0.00925
44	0.00320	0.00008	0.04812	0.00000	0.00000	0.00436	0.00000	0.00000	0.00893
45	0.00306	0.00007	0.04711	0.00000	0.00000	0.00419	0.00000	0.00000	0.00863
46	0.00292	0.00006	0.04614	0.00000	0.00000	0.00403	0.00000	0.00000	0.00835
47	0.00279	0.00006	0.04520	0.00000	0.00000	0.00387	0.00000	0.00000	0.00808
48	0.00267	0.00006	0.04430	0.00000	0.00000	0.00372	0.00000	0.00000	0.00782
49	0.00256	0.00005	0.04344	0.00000	0.00000	0.00359	0.00000	0.00000	0.00758
50	0.00245	0.00005	0.04260	0.00000	0.00000	0.00346	0.00000	0.00000	0.00734
55	0.00200	0.00003	0.03884	0.00000	0.00000	0.00289	0.00000	0.00000	0.00632
60	0.00165	0.00002	0.03566	0.00000	0.00000	0.00246	0.00000	0.00000	0.00551
65	0.00138	0.00002	0.03292	0.00000	0.00000	0.00211	0.00000	0.00000	0.00484
70	0.00117	0.00001	0.03056	0.00000	0.00000	0.00182	0.00000	0.00000	0.00429
75	0.00100	0.00001	0.02848	0.00000	0.00000	0.00159	0.00000	0.00000	0.00383
80	0.00086	0.00001	0.02665	0.00000	0.00000	0.00140	0.00000	0.00000	0.00344
85	0.00075	0.00001	0.02503	0.00000	0.00000	0.00124	0.00000	0.00000	0.00310
90	0.00065	0.00000	0.02357	0.00000	0.00000	0.00110	0.00000	0.00000	0.00282
95	0.00057	0.00000	0.02226	0.00000	0.00000	0.00099	0.00000	0.00000	0.00257
100	0.00051	0.00000	0.02108	0.00000	0.00000	0.00089	0.00000	0.00000	0.00235
110	0.00040	0.00000	0.01902	0.00000	0.00000	0.00073	0.00000	0.00000	0.00199
120	0.00032	0.00000	0.01730	0.00000	0.00000	0.00061	0.00000	0.00000	0.00171
130	0.00026	0.00000	0.01584	0.00000	0.00000	0.00051	0.00000	0.00000	0.00148
140	0.00022	0.00000	0.01458	0.00000	0.00000	0.00044	0.00000	0.00000	0.00129
150	0.00018	0.00000	0.01349	0.00000	0.00000	0.00037	0.00000	0.00000	0.00114
160	0.00015	0.00000	0.01254	0.00000	0.00000	0.00032	0.00000	0.00000	0.00101
170	0.00013	0.00000	0.01169	0.00000	0.00000	0.00028	0.00000	0.00000	0.00090
180	0.00011	0.00000	0.01095	0.00000	0.00000	0.00025	0.00000	0.00000	0.00081
190	0.00010	0.00000	0.01028	0.00000	0.00000	0.00022	0.00000	0.00000	0.00073
200	0.00008	0.00000	0.00968	0.00000	0.00000	0.00020	0.00000	0.00000	0.00066

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sb			Sbs			Se		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00007	0.00000	0.00913	0.00000	0.00000	0.00018	0.00000	0.00000	0.00060
220	0.00007	0.00000	0.00864	0.00000	0.00000	0.00016	0.00000	0.00000	0.00055
230	0.00006	0.00000	0.00819	0.00000	0.00000	0.00014	0.00000	0.00000	0.00051
240	0.00005	0.00000	0.00778	0.00000	0.00000	0.00013	0.00000	0.00000	0.00046
250	0.00005	0.00000	0.00741	0.00000	0.00000	0.00012	0.00000	0.00000	0.00043
260	0.00004	0.00000	0.00706	0.00000	0.00000	0.00011	0.00000	0.00000	0.00040
270	0.00004	0.00000	0.00675	0.00000	0.00000	0.00010	0.00000	0.00000	0.00037
280	0.00003	0.00000	0.00645	0.00000	0.00000	0.00009	0.00000	0.00000	0.00034
290	0.00003	0.00000	0.00618	0.00000	0.00000	0.00008	0.00000	0.00000	0.00032
300	0.00003	0.00000	0.00592	0.00000	0.00000	0.00008	0.00000	0.00000	0.00030

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			So			SOagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.31386	0.10546	0.61071	0.32432	0.15913	0.53458	0.27049	0.11302	0.49520
2	0.18569	0.03382	0.51582	0.21113	0.08202	0.41552	0.20019	0.06910	0.42098
3	0.12859	0.01344	0.47890	0.15735	0.05103	0.35351	0.16471	0.04947	0.38190
4	0.09632	0.00620	0.45806	0.12521	0.03497	0.31333	0.14218	0.03819	0.35605
5	0.07572	0.00318	0.44411	0.10365	0.02546	0.28437	0.12621	0.03085	0.33704
6	0.06153	0.00176	0.43385	0.08815	0.01934	0.26212	0.11412	0.02570	0.32214
7	0.05124	0.00104	0.42584	0.07645	0.01515	0.24429	0.10457	0.02190	0.30999
8	0.04347	0.00064	0.41932	0.06730	0.01216	0.22956	0.09677	0.01898	0.29977
9	0.03744	0.00041	0.41385	0.05996	0.00995	0.21711	0.09025	0.01667	0.29099
10	0.03264	0.00027	0.40917	0.05393	0.00827	0.20639	0.08470	0.01481	0.28333
11	0.02874	0.00019	0.40509	0.04891	0.00697	0.19703	0.07991	0.01327	0.27653
12	0.02553	0.00013	0.40147	0.04465	0.00594	0.18876	0.07571	0.01199	0.27045
13	0.02285	0.00009	0.39824	0.04100	0.00511	0.18139	0.07200	0.01090	0.26496
14	0.02058	0.00007	0.39532	0.03785	0.00444	0.17475	0.06870	0.00997	0.25995
15	0.01864	0.00005	0.39266	0.03509	0.00388	0.16874	0.06572	0.00916	0.25536
16	0.01698	0.00004	0.39022	0.03266	0.00342	0.16326	0.06303	0.00846	0.25112
17	0.01553	0.00003	0.38797	0.03051	0.00303	0.15823	0.06058	0.00784	0.24720
18	0.01426	0.00002	0.38588	0.02859	0.00269	0.15360	0.05834	0.00729	0.24354
19	0.01314	0.00002	0.38394	0.02686	0.00241	0.14931	0.05629	0.00680	0.24013
20	0.01215	0.00001	0.38212	0.02531	0.00217	0.14533	0.05439	0.00637	0.23692
21	0.01127	0.00001	0.38041	0.02390	0.00196	0.14162	0.05263	0.00597	0.23391
22	0.01048	0.00001	0.37880	0.02262	0.00177	0.13815	0.05099	0.00562	0.23106
23	0.00978	0.00001	0.37728	0.02145	0.00161	0.13489	0.04947	0.00530	0.22837
24	0.00914	0.00001	0.37584	0.02038	0.00147	0.13183	0.04804	0.00500	0.22581
25	0.00856	0.00000	0.37447	0.01940	0.00134	0.12894	0.04671	0.00474	0.22338
26	0.00804	0.00000	0.37317	0.01849	0.00123	0.12622	0.04545	0.00449	0.22107
27	0.00756	0.00000	0.37193	0.01765	0.00113	0.12363	0.04427	0.00427	0.21886
28	0.00713	0.00000	0.37074	0.01687	0.00105	0.12119	0.04316	0.00406	0.21675
29	0.00673	0.00000	0.36960	0.01615	0.00097	0.11886	0.04210	0.00387	0.21473
30	**0.00636**	**0.00000**	**0.36851**	**0.01548**	**0.00089**	**0.11664**	**0.04110**	**0.00369**	**0.21279**
31	0.00602	0.00000	0.36747	0.01485	0.00083	0.11453	0.04015	0.00352	0.21093
32	0.00571	0.00000	0.36646	0.01427	0.00077	0.11252	0.03925	0.00337	0.20914
33	0.00542	0.00000	0.36549	0.01372	0.00072	0.11059	0.03840	0.00323	0.20742
34	0.00515	0.00000	0.36456	0.01320	0.00067	0.10874	0.03758	0.00309	0.20576
35	0.00491	0.00000	0.36366	0.01272	0.00063	0.10698	0.03680	0.00297	0.20415

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			So			SOagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00467	0.00000	0.36278	0.01226	0.00059	0.10528	0.03605	0.00285	0.20261
37	0.00446	0.00000	0.36194	0.01183	0.00055	0.10365	0.03534	0.00274	0.20111
38	0.00426	0.00000	0.36113	0.01143	0.00052	0.10208	0.03466	0.00264	0.19966
39	0.00407	0.00000	0.36034	0.01104	0.00048	0.10057	0.03400	0.00254	0.19826
40	0.00389	0.00000	0.35957	0.01068	0.00046	0.09912	0.03338	0.00245	0.19690
41	0.00373	0.00000	0.35882	0.01034	0.00043	0.09772	0.03277	0.00236	0.19559
42	0.00357	0.00000	0.35810	0.01001	0.00041	0.09637	0.03219	0.00228	0.19431
43	0.00343	0.00000	0.35740	0.00970	0.00038	0.09506	0.03163	0.00220	0.19306
44	0.00329	0.00000	0.35672	0.00941	0.00036	0.09380	0.03110	0.00213	0.19186
45	0.00316	0.00000	0.35605	0.00913	0.00034	0.09257	0.03058	0.00206	0.19068
46	0.00304	0.00000	0.35540	0.00886	0.00032	0.09139	0.03008	0.00199	0.18954
47	0.00292	0.00000	0.35477	0.00860	0.00031	0.09025	0.02960	0.00193	0.18842
48	0.00281	0.00000	0.35415	0.00836	0.00029	0.08914	0.02913	0.00187	0.18734
49	0.00271	0.00000	0.35355	0.00813	0.00028	0.08806	0.02868	0.00181	0.18628
50	0.00261	0.00000	0.35296	0.00791	0.00026	0.08702	0.02824	0.00176	0.18525
55	0.00219	0.00000	0.35022	0.00693	0.00021	0.08222	0.02626	0.00152	0.18044
60	0.00186	0.00000	0.34776	0.00613	0.00017	0.07803	0.02455	0.00133	0.17614
65	0.00160	0.00000	0.34552	0.00547	0.00013	0.07433	0.02307	0.00117	0.17226
70	0.00139	0.00000	0.34347	0.00492	0.00011	0.07102	0.02176	0.00104	0.16872
75	0.00121	0.00000	0.34159	0.00445	0.00009	0.06806	0.02060	0.00093	0.16549
80	0.00107	0.00000	0.33984	0.00404	0.00008	0.06538	0.01956	0.00084	0.16250
85	0.00095	0.00000	0.33822	0.00370	0.00007	0.06294	0.01862	0.00076	0.15974
90	0.00085	0.00000	0.33670	0.00339	0.00006	0.06071	0.01778	0.00069	0.15717
95	0.00076	0.00000	0.33527	0.00313	0.00005	0.05866	0.01701	0.00063	0.15477
100	0.00068	0.00000	0.33393	0.00289	0.00004	0.05676	0.01630	0.00058	0.15252
110	0.00056	0.00000	0.33146	0.00249	0.00003	0.05338	0.01506	0.00050	0.14840
120	0.00047	0.00000	0.32923	0.00218	0.00002	0.05044	0.01400	0.00043	0.14472
130	0.00040	0.00000	0.32720	0.00192	0.00002	0.04785	0.01308	0.00037	0.14141
140	0.00034	0.00000	0.32534	0.00170	0.00002	0.04556	0.01228	0.00033	0.13839
150	0.00029	0.00000	0.32362	0.00152	0.00001	0.04350	0.01157	0.00029	0.13562
160	0.00025	0.00000	0.32202	0.00137	0.00001	0.04165	0.01094	0.00026	0.13308
170	0.00022	0.00000	0.32054	0.00124	0.00001	0.03997	0.01037	0.00023	0.13072
180	0.00019	0.00000	0.31914	0.00113	0.00001	0.03844	0.00986	0.00021	0.12853
190	0.00017	0.00000	0.31784	0.00103	0.00001	0.03704	0.00940	0.00019	0.12649
200	0.00015	0.00000	0.31660	0.00095	0.00001	0.03575	0.00898	0.00017	0.12457

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Sgr			So			SOagr		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00014	0.00000	0.31543	0.00087	0.00000	0.03456	0.00859	0.00016	0.12277
220	0.00012	0.00000	0.31433	0.00080	0.00000	0.03346	0.00824	0.00014	0.12107
230	0.00011	0.00000	0.31327	0.00074	0.00000	0.03243	0.00792	0.00013	0.11947
240	0.00010	0.00000	0.31227	0.00069	0.00000	0.03147	0.00761	0.00012	0.11795
250	0.00009	0.00000	0.31131	0.00064	0.00000	0.03057	0.00734	0.00011	0.11651
260	0.00008	0.00000	0.31039	0.00060	0.00000	0.02973	0.00708	0.00011	0.11513
270	0.00008	0.00000	0.30951	0.00056	0.00000	0.02894	0.00683	0.00010	0.11382
280	0.00007	0.00000	0.30867	0.00053	0.00000	0.02820	0.00661	0.00009	0.11257
290	0.00006	0.00000	0.30786	0.00050	0.00000	0.02749	0.00639	0.00009	0.11138
300	0.00006	0.00000	0.30707	0.00047	0.00000	0.02683	0.00620	0.00008	0.11023

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SObo			Sp			Spsq*		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.48976	0.21348	0.77127	0.29427	0.16239	0.46127	0.0595698	0.011175	0.202584
2	0.39909	0.15728	0.68945	0.21950	0.10626	0.38165	0.0294494	0.0043667	0.123926
3	0.34817	0.12548	0.64337	0.18137	0.07987	0.33930	0.0186571	0.0023951	0.089506
4	0.31358	0.10434	0.61246	0.15701	0.06409	0.31122	0.0132263	0.0015282	0.069838
5	0.28781	0.08910	0.58970	0.13966	0.05349	0.29057	0.0100116	0.0010642	0.05704
6	0.26754	0.07753	0.57195	0.12650	0.04583	0.27442	0.0079139	0.0007848	0.048033
7	0.25097	0.06843	0.55754	0.11606	0.04003	0.26127	0.0064526	0.000603	0.041346
8	0.23707	0.06108	0.54550	0.10753	0.03547	0.25024	0.0053853	0.0004777	0.036188
9	0.22517	0.05502	0.53521	0.10038	0.03180	0.24080	0.0045774	0.0003876	0.032091
10	0.21482	0.04994	0.52626	0.09429	0.02877	0.23257	0.0039482	0.0003206	0.02876
11	0.20570	0.04562	0.51838	0.08902	0.02624	0.22530	0.003447	0.0002694	0.026002
12	0.19758	0.04190	0.51134	0.08440	0.02408	0.21881	0.0030402	0.0002293	0.023682
13	0.19028	0.03867	0.50501	0.08032	0.02223	0.21296	0.0027047	0.0001975	0.021705
14	0.18367	0.03584	0.49927	0.07667	0.02062	0.20765	0.0024243	0.0001717	0.020001
15	0.17765	0.03335	0.49401	0.07338	0.01921	0.20279	0.0021871	0.0001506	0.01852
16	0.17213	0.03113	0.48918	0.07041	0.01796	0.19832	0.0019846	0.000133	0.01722
17	0.16705	0.02915	0.48472	0.06771	0.01685	0.19419	0.0018099	0.0001183	0.016071
18	0.16235	0.02737	0.48057	0.06523	0.01586	0.19036	0.0016582	0.0001058	0.015049
19	0.15798	0.02576	0.47670	0.06295	0.01496	0.18678	0.0015255	0.0000951	0.014135
20	0.15391	0.02430	0.47307	0.06085	0.01415	0.18343	0.0014086	0.000086	0.013312
21	0.15010	0.02297	0.46967	0.05890	0.01342	0.18029	0.001305	0.000078	0.012569
22	0.14653	0.02176	0.46646	0.05708	0.01274	0.17733	0.0012128	0.0000711	0.011894
23	0.14317	0.02065	0.46342	0.05539	0.01213	0.17454	0.0011303	0.000065	0.011279
24	0.14000	0.01962	0.46055	0.05381	0.01157	0.17190	0.0010562	0.0000596	0.010716
25	0.13700	0.01868	0.45782	0.05233	0.01104	0.16939	0.0009893	0.0000549	0.0102
26	0.13417	0.01781	0.45523	0.05093	0.01056	0.16701	0.0009287	0.0000506	0.009725
27	0.13148	0.01700	0.45275	0.04962	0.01012	0.16474	0.0008736	0.0000469	0.009286
28	0.12893	0.01625	0.45039	0.04838	0.00970	0.16258	0.0008234	0.0000435	0.008879
29	0.12649	0.01555	0.44812	0.04720	0.00932	0.16051	0.0007775	0.0000404	0.008502
30	**0.12417**	**0.01490**	**0.44596**	**0.04609**	**0.00896**	**0.15853**	**0.0007354**	**0.0000377**	**0.008151**
31	0.12196	0.01429	0.44388	0.04504	0.00862	0.15663	0.0006967	0.0000352	0.007824
32	0.11984	0.01371	0.44188	0.04403	0.00830	0.15481	0.000661	0.0000329	0.007518
33	0.11781	0.01318	0.43995	0.04308	0.00801	0.15307	0.000628	0.0000309	0.007232
34	0.11586	0.01268	0.43810	0.04217	0.00773	0.15138	0.0005975	0.000029	0.006964
35	0.11400	0.01220	0.43631	0.04130	0.00746	0.14976	0.0005692	0.0000272	0.006712

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SObo			Sp			Spsq*		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.11221	0.01176	0.43458	0.04047	0.00722	0.14820	0.0005428	0.0000257	0.006475
37	0.11048	0.01133	0.43291	0.03968	0.00698	0.14670	0.0005183	0.0000242	0.006251
38	0.10882	0.01094	0.43130	0.03891	0.00676	0.14524	0.0004954	0.0000229	0.00604
39	0.10722	0.01056	0.42973	0.03818	0.00655	0.14383	0.000474	0.0000216	0.005841
40	0.10568	0.01020	0.42822	0.03748	0.00635	0.14247	0.000454	0.0000205	0.005653
41	0.10419	0.00987	0.42675	0.03681	0.00616	0.14116	0.0004352	0.0000194	0.005474
42	0.10275	0.00955	0.42532	0.03616	0.00598	0.13988	0.0004176	0.0000184	0.005305
43	0.10136	0.00924	0.42393	0.03554	0.00581	0.13864	0.0004011	0.0000175	0.005144
44	0.10001	0.00895	0.42259	0.03494	0.00565	0.13744	0.0003855	0.0000167	0.004991
45	0.09871	0.00867	0.42128	0.03436	0.00549	0.13627	0.0003708	0.0000159	0.004845
46	0.09745	0.00841	0.42000	0.03380	0.00534	0.13514	0.0003569	0.0000151	0.004706
47	0.09623	0.00816	0.41876	0.03326	0.00520	0.13403	0.0003438	0.0000144	0.004574
48	0.09504	0.00792	0.41755	0.03274	0.00507	0.13296	0.0003314	0.0000138	0.004448
49	0.09389	0.00769	0.41637	0.03224	0.00494	0.13192	0.0003197	0.0000132	0.004327
50	0.09277	0.00747	0.41521	0.03175	0.00481	0.13090	0.0003085	0.0000126	0.004212
55	0.08762	0.00651	0.40984	0.02953	0.00426	0.12618	0.0002608	0.0000102	0.003704
60	0.08312	0.00573	0.40503	0.02762	0.00381	0.12199	0.0002233	0.0000084	0.00329
65	0.07913	0.00508	0.40068	0.02596	0.00343	0.11823	0.0001933	0.000007	0.002946
70	0.07556	0.00454	0.39672	0.02449	0.00311	0.11483	0.0001689	0.0000059	0.002657
75	0.07236	0.00408	0.39308	0.02319	0.00283	0.11173	0.0001488	0.000005	0.002412
80	0.06945	0.00369	0.38972	0.02203	0.00260	0.10890	0.0001321	0.0000043	0.002201
85	0.06681	0.00335	0.38660	0.02098	0.00239	0.10628	0.000118	0.0000038	0.002018
90	0.06439	0.00305	0.38369	0.02003	0.00221	0.10386	0.000106	0.0000033	0.001859
95	0.06216	0.00280	0.38096	0.01916	0.00205	0.10161	0.0000957	0.0000029	0.001719
100	0.06010	0.00257	0.37840	0.01837	0.00191	0.09952	0.0000868	0.0000026	0.001595
110	0.05642	0.00219	0.37371	0.01698	0.00167	0.09571	0.0000724	0.000002	0.001386
120	0.05322	0.00189	0.36950	0.01578	0.00147	0.09234	0.0000611	0.0000016	0.001217
130	0.05040	0.00165	0.36568	0.01475	0.00131	0.08932	0.0000523	0.0000014	0.001079
140	0.04790	0.00145	0.36219	0.01384	0.00118	0.08659	0.0000452	0.0000011	0.000965
150	0.04566	0.00128	0.35898	0.01305	0.00106	0.08411	0.0000394	0.000001	0.000868
160	0.04364	0.00114	0.35601	0.01233	0.00097	0.08185	0.0000346	0.0000008	0.000786
170	0.04181	0.00102	0.35325	0.01170	0.00088	0.07976	0.0000307	0.0000007	0.000715
180	0.04015	0.00092	0.35068	0.01112	0.00081	0.07784	0.0000273	0.0000006	0.000654
190	0.03862	0.00083	0.34826	0.01060	0.00075	0.07605	0.0000245	0.0000005	0.0006
200	0.03722	0.00076	0.34599	0.01013	0.00069	0.07439	0.000022	0.0000005	0.000553

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SObo			Sp			Spsq*		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.03592	0.00069	0.34384	0.00970	0.00064	0.07283	0.0000199	0.0000004	0.000512
220	0.03472	0.00063	0.34181	0.00930	0.00060	0.07137	0.0000181	0.0000004	0.000475
230	0.03360	0.00058	0.33989	0.00893	0.00056	0.07000	0.0000165	0.0000003	0.000442
240	0.03256	0.00054	0.33806	0.00859	0.00052	0.06871	0.0000151	0.0000003	0.000413
250	0.03159	0.00050	0.33631	0.00828	0.00049	0.06749	0.0000139	0.0000003	0.000386
260	0.03067	0.00046	0.33465	0.00798	0.00046	0.06633	0.0000128	0.0000002	0.000362
270	0.02981	0.00043	0.33305	0.00771	0.00043	0.06523	0.0000118	0.0000002	0.000341
280	0.02901	0.00040	0.33153	0.00745	0.00041	0.06418	0.0000109	0.0000002	0.000321
290	0.02824	0.00037	0.33006	0.00721	0.00038	0.06319	0.0000101	0.0000002	0.000303
300	0.02752	0.00035	0.32865	0.00699	0.00036	0.06224	0.0000094	0.0000002	0.000286

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			St		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.10803	0.01801	0.35292	0.33125	0.15099	0.56326	0.26746	0.12567	0.46258
2	0.05713	0.00474	0.28624	0.22783	0.08919	0.44186	0.16133	0.05813	0.34187
3	0.03757	0.00185	0.25586	0.17694	0.06207	0.37577	0.11419	0.03347	0.28195
4	0.02733	0.00088	0.23708	0.14558	0.04675	0.33218	0.08731	0.02158	0.24424
5	0.02109	0.00048	0.22379	0.12400	0.03693	0.30050	0.06996	0.01493	0.21764
6	0.01693	0.00028	0.21367	0.10811	0.03014	0.27607	0.05786	0.01085	0.19756
7	0.01398	0.00018	0.20555	0.09586	0.02519	0.25646	0.04896	0.00817	0.18170
8	0.01179	0.00012	0.19883	0.08611	0.02145	0.24025	0.04218	0.00634	0.16875
9	0.01012	0.00008	0.19313	0.07814	0.01852	0.22656	0.03684	0.00502	0.15793
10	0.00880	0.00006	0.18819	0.07149	0.01619	0.21479	0.03255	0.00406	0.14871
11	0.00774	0.00004	0.18384	0.06586	0.01429	0.20452	0.02903	0.00333	0.14073
12	0.00687	0.00003	0.17998	0.06103	0.01273	0.19547	0.02610	0.00277	0.13374
13	0.00615	0.00002	0.17650	0.05683	0.01141	0.18740	0.02362	0.00233	0.12756
14	0.00554	0.00002	0.17335	0.05315	0.01030	0.18016	0.02151	0.00198	0.12203
15	0.00502	0.00001	0.17047	0.04990	0.00934	0.17360	0.01969	0.00169	0.11705
16	0.00458	0.00001	0.16783	0.04700	0.00852	0.16763	0.01811	0.00146	0.11255
17	0.00419	0.00001	0.16538	0.04440	0.00781	0.16217	0.01672	0.00127	0.10844
18	0.00386	0.00001	0.16311	0.04206	0.00718	0.15714	0.01550	0.00111	0.10468
19	0.00356	0.00001	0.16100	0.03994	0.00662	0.15250	0.01442	0.00098	0.10121
20	0.00330	0.00000	0.15902	0.03800	0.00613	0.14819	0.01345	0.00087	0.09801
21	0.00307	0.00000	0.15716	0.03624	0.00570	0.14418	0.01258	0.00077	0.09504
22	0.00286	0.00000	0.15540	0.03462	0.00530	0.14044	0.01180	0.00069	0.09228
23	0.00267	0.00000	0.15375	0.03312	0.00495	0.13693	0.01109	0.00061	0.08970
24	0.00251	0.00000	0.15218	0.03174	0.00463	0.13364	0.01044	0.00055	0.08728
25	0.00235	0.00000	0.15069	0.03047	0.00434	0.13054	0.00986	0.00050	0.08502
26	0.00221	0.00000	0.14927	0.02928	0.00408	0.12761	0.00932	0.00045	0.08288
27	0.00209	0.00000	0.14792	0.02817	0.00384	0.12485	0.00883	0.00041	0.08087
28	0.00197	0.00000	0.14663	0.02714	0.00362	0.12223	0.00838	0.00037	0.07897
29	0.00187	0.00000	0.14540	0.02617	0.00342	0.11974	0.00796	0.00034	0.07717
30	**0.00177**	**0.00000**	**0.14422**	**0.02527**	**0.00324**	**0.11738**	**0.00758**	**0.00031**	**0.07546**
31	0.00168	0.00000	0.14308	0.02442	0.00307	0.11513	0.00722	0.00029	0.07384
32	0.00160	0.00000	0.14199	0.02362	0.00291	0.11298	0.00689	0.00026	0.07230
33	0.00152	0.00000	0.14094	0.02286	0.00277	0.11093	0.00658	0.00024	0.07083
34	0.00145	0.00000	0.13993	0.02215	0.00263	0.10897	0.00630	0.00022	0.06942
35	0.00138	0.00000	0.13896	0.02147	0.00251	0.10709	0.00603	0.00021	0.06808

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			St		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.00132	0.00000	0.13802	0.02083	0.00239	0.10529	0.00578	0.00019	0.06680
37	0.00126	0.00000	0.13711	0.02023	0.00228	0.10357	0.00554	0.00018	0.06557
38	0.00121	0.00000	0.13623	0.01965	0.00218	0.10191	0.00532	0.00017	0.06439
39	0.00116	0.00000	0.13538	0.01911	0.00208	0.10031	0.00511	0.00015	0.06326
40	0.00111	0.00000	0.13456	0.01859	0.00199	0.09878	0.00492	0.00014	0.06218
41	0.00107	0.00000	0.13376	0.01809	0.00191	0.09730	0.00473	0.00013	0.06113
42	0.00103	0.00000	0.13299	0.01762	0.00183	0.09587	0.00456	0.00013	0.06013
43	0.00099	0.00000	0.13223	0.01717	0.00176	0.09450	0.00440	0.00012	0.05916
44	0.00095	0.00000	0.13150	0.01673	0.00169	0.09317	0.00424	0.00011	0.05822
45	0.00091	0.00000	0.13079	0.01632	0.00162	0.09189	0.00409	0.00010	0.05732
46	0.00088	0.00000	0.13010	0.01592	0.00156	0.09064	0.00396	0.00010	0.05645
47	0.00085	0.00000	0.12943	0.01555	0.00150	0.08944	0.00382	0.00009	0.05561
48	0.00082	0.00000	0.12877	0.01518	0.00145	0.08828	0.00370	0.00009	0.05480
49	0.00079	0.00000	0.12813	0.01483	0.00139	0.08715	0.00358	0.00008	0.05401
50	0.00077	0.00000	0.12751	0.01450	0.00134	0.08606	0.00347	0.00008	0.05325
55	0.00065	0.00000	0.12460	0.01300	0.00113	0.08105	0.00297	0.00006	0.04978
60	0.00056	0.00000	0.12200	0.01176	0.00096	0.07668	0.00258	0.00005	0.04677
65	0.00049	0.00000	0.11966	0.01070	0.00083	0.07284	0.00226	0.00004	0.04414
70	0.00043	0.00000	0.11753	0.00980	0.00072	0.06943	0.00199	0.00003	0.04182
75	0.00038	0.00000	0.11557	0.00902	0.00063	0.06637	0.00177	0.00002	0.03975
80	0.00034	0.00000	0.11377	0.00835	0.00055	0.06362	0.00159	0.00002	0.03789
85	0.00030	0.00000	0.11210	0.00775	0.00049	0.06111	0.00143	0.00002	0.03622
90	0.00027	0.00000	0.11055	0.00722	0.00044	0.05883	0.00130	0.00001	0.03469
95	0.00025	0.00000	0.10910	0.00675	0.00039	0.05674	0.00118	0.00001	0.03330
100	0.00022	0.00000	0.10774	0.00633	0.00035	0.05481	0.00108	0.00001	0.03203
110	0.00019	0.00000	0.10525	0.00561	0.00029	0.05137	0.00091	0.00001	0.02977
120	0.00016	0.00000	0.10303	0.00502	0.00024	0.04839	0.00077	0.00001	0.02783
130	0.00014	0.00000	0.10102	0.00452	0.00021	0.04578	0.00067	0.00000	0.02614
140	0.00012	0.00000	0.09919	0.00410	0.00018	0.04348	0.00058	0.00000	0.02465
150	0.00010	0.00000	0.09752	0.00375	0.00015	0.04142	0.00051	0.00000	0.02333
160	0.00009	0.00000	0.09597	0.00344	0.00013	0.03957	0.00045	0.00000	0.02216
170	0.00008	0.00000	0.09454	0.00317	0.00012	0.03789	0.00040	0.00000	0.02110
180	0.00007	0.00000	0.09321	0.00293	0.00010	0.03637	0.00036	0.00000	0.02014
190	0.00007	0.00000	0.09196	0.00272	0.00009	0.03498	0.00033	0.00000	0.01927
200	0.00006	0.00000	0.09080	0.00253	0.00008	0.03370	0.00029	0.00000	0.01847

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	Spss			Ssqd			St		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.00005	0.00000	0.08970	0.00237	0.00007	0.03253	0.00027	0.00000	0.01774
220	0.00005	0.00000	0.08866	0.00222	0.00006	0.03144	0.00024	0.00000	0.01707
230	0.00004	0.00000	0.08768	0.00209	0.00006	0.03043	0.00022	0.00000	0.01645
240	0.00004	0.00000	0.08675	0.00196	0.00005	0.02948	0.00021	0.00000	0.01587
250	0.00004	0.00000	0.08587	0.00185	0.00005	0.02860	0.00019	0.00000	0.01533
260	0.00003	0.00000	0.08503	0.00175	0.00004	0.02778	0.00017	0.00000	0.01483
270	0.00003	0.00000	0.08422	0.00166	0.00004	0.02701	0.00016	0.00000	0.01436
280	0.00003	0.00000	0.08346	0.00157	0.00004	0.02628	0.00015	0.00000	0.01393
290	0.00003	0.00000	0.08272	0.00150	0.00003	0.02559	0.00014	0.00000	0.01351
300	0.00003	0.00000	0.08202	0.00142	0.00003	0.02495	0.00013	0.00000	0.01313

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SZtb			Zpg			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
1	0.0700933	0.0257274	0.158045	0.49898	0.26915	0.72915	0.92117	0.78082	0.97987
2	0.0383324	0.0105027	0.108813	0.38066	0.18437	0.61461	0.80805	0.63687	0.91795
3	0.026002	0.0058299	0.086296	0.31565	0.14087	0.54642	0.71006	0.53474	0.84611
4	0.0194307	0.0037291	0.072746	0.27262	0.11357	0.49918	0.62873	0.45674	0.77806
5	0.0153589	0.002593	0.063483	0.24138	0.09466	0.46369	0.56117	0.39469	0.71735
6	0.0125982	0.001906	0.05666	0.21738	0.08075	0.43561	0.50451	0.34407	0.66421
7	0.01061	0.0014581	0.051377	0.19820	0.07007	0.41260	0.45649	0.30207	0.61787
8	0.0091146	0.0011495	0.047139	0.18245	0.06163	0.39324	0.41537	0.26677	0.57735
9	0.0079521	0.0009279	0.043648	0.16922	0.05478	0.37663	0.37985	0.23682	0.54174
10	0.0070249	0.0007635	0.040712	0.15792	0.04913	0.36215	0.34890	0.21119	0.51024
11	0.0062697	0.0006382	0.038202	0.14814	0.04439	0.34936	0.32173	0.18912	0.48222
12	0.005644	0.0005406	0.036025	0.13957	0.04037	0.33795	0.29773	0.17000	0.45712
13	0.005118	0.0004631	0.034117	0.13199	0.03691	0.32767	0.27641	0.15334	0.43452
14	0.0046704	0.0004006	0.032428	0.12523	0.03391	0.31835	0.25735	0.13875	0.41406
15	0.0042854	0.0003495	0.030919	0.11916	0.03129	0.30984	0.24025	0.12593	0.39545
16	0.0039512	0.0003072	0.029563	0.11367	0.02899	0.30202	0.22483	0.11461	0.37843
17	0.0036588	0.0002719	0.028336	0.10868	0.02694	0.29480	0.21087	0.10458	0.36282
18	0.003401	0.000242	0.027219	0.10412	0.02512	0.28811	0.19818	0.09566	0.34843
19	0.0031723	0.0002166	0.026197	0.09994	0.02349	0.28188	0.18662	0.08770	0.33513
20	0.0029683	0.0001948	0.025258	0.09608	0.02201	0.27606	0.17604	0.08058	0.32280
21	0.0027852	0.000176	0.024392	0.09252	0.02068	0.27060	0.16634	0.07418	0.31132
22	0.0026202	0.0001597	0.023591	0.08921	0.01948	0.26548	0.15742	0.06843	0.30062
23	0.0024709	0.0001454	0.022846	0.08614	0.01838	0.26064	0.14920	0.06324	0.29061
24	0.0023352	0.0001328	0.022152	0.08327	0.01737	0.25607	0.14160	0.05854	0.28123
25	0.0022114	0.0001217	0.021504	0.08058	0.01645	0.25175	0.13456	0.05428	0.27241
26	0.002098	0.0001119	0.020897	0.07807	0.01560	0.24764	0.12802	0.05041	0.26411
27	0.001994	0.0001032	0.020326	0.07570	0.01482	0.24374	0.12195	0.04689	0.25629
28	0.0018982	0.0000953	0.019789	0.07347	0.01410	0.24002	0.11629	0.04367	0.24890
29	0.0018097	0.0000883	0.019283	0.07137	0.01343	0.23647	0.11100	0.04073	0.24190
30	**0.0017279**	**0.000082**	**0.018805**	**0.06939**	**0.01281**	**0.23308**	**0.10606**	**0.03804**	**0.23527**
31	0.0016519	0.0000763	0.018352	0.06751	0.01223	0.22984	0.10144	0.03557	0.22897
32	0.0015812	0.0000711	0.017922	0.06572	0.01169	0.22673	0.09711	0.03331	0.22299
33	0.0015154	0.0000664	0.017515	0.06403	0.01119	0.22375	0.09304	0.03122	0.21729
34	0.0014539	0.0000621	0.017127	0.06242	0.01072	0.22088	0.08921	0.02929	0.21186
35	0.0013964	0.0000582	0.016757	0.06089	0.01027	0.21813	0.08561	0.02751	0.20668

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SZtb			Zpg			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
36	0.0013426	0.0000547	0.016405	0.05943	0.00986	0.21547	0.08221	0.02587	0.20173
37	0.001292	0.0000514	0.016068	0.05803	0.00947	0.21292	0.07900	0.02435	0.19700
38	0.0012444	0.0000484	0.015746	0.05670	0.00911	0.21045	0.07598	0.02294	0.19247
39	0.0011997	0.0000456	0.015438	0.05543	0.00876	0.20807	0.07311	0.02163	0.18813
40	0.0011574	0.000043	0.015143	0.05421	0.00843	0.20577	0.07040	0.02042	0.18396
41	0.0011176	0.0000407	0.01486	0.05304	0.00813	0.20354	0.06784	0.01929	0.17997
42	0.0010799	0.0000385	0.014589	0.05191	0.00784	0.20139	0.06540	0.01823	0.17613
43	0.0010442	0.0000365	0.014327	0.05084	0.00756	0.19930	0.06309	0.01725	0.17244
44	0.0010104	0.0000346	0.014076	0.04980	0.00730	0.19728	0.06089	0.01634	0.16889
45	0.0009784	0.0000328	0.013834	0.04881	0.00705	0.19531	0.05880	0.01548	0.16547
46	0.0009479	0.0000312	0.013601	0.04785	0.00682	0.19341	0.05681	0.01468	0.16217
47	0.000919	0.0000297	0.013377	0.04692	0.00659	0.19156	0.05492	0.01393	0.15899
48	0.0008914	0.0000283	0.01316	0.04603	0.00638	0.18976	0.05311	0.01323	0.15593
49	0.0008652	0.0000269	0.012951	0.04518	0.00618	0.18801	0.05139	0.01257	0.15296
50	0.0008401	0.0000257	0.012749	0.04435	0.00598	0.18631	0.04974	0.01195	0.15010
55	0.0007308	0.0000205	0.011832	0.04060	0.00514	0.17845	0.04254	0.00937	0.13714
60	0.0006426	0.0000166	0.011046	0.03741	0.00446	0.17149	0.03673	0.00745	0.12606
65	0.0005702	0.0000137	0.010364	0.03466	0.00391	0.16528	0.03197	0.00600	0.11648
70	0.00051	0.0000114	0.009766	0.03226	0.00345	0.15969	0.02803	0.00488	0.10812
75	0.0004593	0.0000097	0.009237	0.03016	0.00307	0.15462	0.02473	0.00400	0.10076
80	0.0004162	0.0000082	0.008766	0.02829	0.00275	0.14999	0.02195	0.00332	0.09423
85	0.0003791	0.0000071	0.008342	0.02663	0.00247	0.14575	0.01958	0.00277	0.08841
90	0.0003469	0.0000061	0.00796	0.02513	0.00223	0.14183	0.01755	0.00233	0.08318
95	0.0003189	0.0000053	0.007613	0.02378	0.00203	0.13820	0.01580	0.00197	0.07846
100	0.0002942	0.0000047	0.007296	0.02256	0.00185	0.13483	0.01428	0.00167	0.07419
110	0.0002531	0.0000037	0.006738	0.02043	0.00155	0.12873	0.01178	0.00123	0.06674
120	0.0002203	0.0000029	0.006262	0.01864	0.00132	0.12336	0.00985	0.00092	0.06048
130	0.0001936	0.0000024	0.005851	0.01711	0.00113	0.11857	0.00831	0.00070	0.05515
140	0.0001717	0.0000019	0.005492	0.01579	0.00098	0.11428	0.00709	0.00055	0.05057
150	0.0001533	0.0000016	0.005176	0.01464	0.00086	0.11040	0.00609	0.00043	0.04659
160	0.0001379	0.0000014	0.004896	0.01363	0.00076	0.10686	0.00528	0.00034	0.04310
170	0.0001247	0.0000012	0.004644	0.01274	0.00067	0.10362	0.00460	0.00027	0.04002
180	0.0001133	0.000001	0.004418	0.01195	0.00060	0.10064	0.00403	0.00022	0.03730
190	0.0001035	0.0000009	0.004214	0.01123	0.00054	0.09788	0.00355	0.00018	0.03486
200	0.0000949	0.0000007	0.004027	0.01059	0.00048	0.09533	0.00315	0.00015	0.03267

Appendix 5. Probability of uranium exceeding a given concentration, by bedrock unit.—Continued

[Probabilities with bold typeface apply to concentrations at the U.S. Environmental Protection Agency drinking-water standard for public supplies. Multiply probability values by 100 to obtain percent probability; *, fewer than five analyses were above the analytical reporting limit and the option to assume a common scale was used in the distribution fitting]

Uranium, in micrograms per liter	Bedrock unit abbreviation								
	SZtb			Zpg			Zsg		
	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound	Probability of concentration being greater than concentration listed in first column	Lower 95-percent confidence bound	Upper 95-percent confidence bound
210	0.0000874	0.0000006	0.003857	0.01001	0.00044	0.09295	0.00280	0.00012	0.03070
220	0.0000807	0.0000006	0.003701	0.00949	0.00040	0.09072	0.00251	0.00010	0.02892
230	0.0000748	0.0000005	0.003557	0.00901	0.00036	0.08863	0.00225	0.00009	0.02730
240	0.0000695	0.0000004	0.003424	0.00857	0.00033	0.08667	0.00202	0.00007	0.02582
250	0.0000648	0.0000004	0.0033	0.00816	0.00030	0.08483	0.00183	0.00006	0.02446
260	0.0000605	0.0000004	0.003186	0.00779	0.00028	0.08308	0.00166	0.00005	0.02322
270	0.0000567	0.0000003	0.003079	0.00745	0.00026	0.08143	0.00151	0.00004	0.02207
280	0.0000532	0.0000003	0.002979	0.00713	0.00024	0.07987	0.00137	0.00004	0.02102
290	0.00005	0.0000003	0.002885	0.00683	0.00022	0.07838	0.00125	0.00003	0.02004
300	0.0000471	0.0000002	0.002797	0.00655	0.00020	0.07697	0.00115	0.00003	0.01913

Appendix 6. Uranium Log-Normal Fit Statistics by Bedrock Unit

Appendix 6. Uranium log-normal fit statistics by bedrock unit.

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Dcgr					Dfgr				
Censoring information		Count			Censoring information		Count		
Uncensored value		7			Uncensored value		8		
Left censored value		0			Left censored value		0		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					Parameter estimates				
Parameter	Estimate	Standard error	95% normal CI		Parameter	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Location	2.31035	0.548184	1.23593	3.38477	Location	0.872357	0.890096	-0.872199	2.61691
Scale	1.35299	0.49093	0.664417	2.75519	Scale	2.33772	0.529608	1.49953	3.64445
Log-likelihood		-29.247			Log-likelihood		-32.057		
Goodness-of-fit					Goodness-of-fit				
Anderson-Darling (adjusted)		3.306			Anderson-Darling (adjusted)		2.951		
Correlation coefficient		0.957			Correlation coefficient		0.973		
Characteristics of distribution					Characteristics of distribution				
Descriptor	Estimate	Standard error	95% normal CI		Descriptor	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Mean	25.1698	17.4269	6.47937	97.7751	Mean	36.7756	45.1462	3.31599	407.855
Standard deviation	57.6032	78.2128	4.02436	824.511	Standard deviation	564.077	1.30×10^3	6.16399	5.16×10^4
Median	10.0779	5.52457	3.44157	29.5112	Median	2.39254	2.12959	0.418031	13.6934
First quartile (Q1)	4.04616	2.97585	0.957207	17.1033	First quartile (Q1)	0.494398	0.531543	0.0601067	4.06659
Third quartile (Q3)	25.1016	13.2678	8.90814	70.7318	Third quartile (Q3)	11.5782	9.57458	2.28952	58.5518
Interquartile range (IQR)	21.0554	12.088	6.83416	64.8697	Interquartile range (IQR)	11.0838	9.18399	2.1847	56.2328

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
DI					**DSw**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		9			Uncensored value		8		
Left censored value		0			Left censored value		0		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-1.42001	0.492276	-2.38486	-0.455172	Location	-0.82093	0.518637	-1.83744	0.19558
Scale	1.4107	0.415304	0.792216	2.51203	Scale	1.40474	0.552648	0.64971	3.0372
Log-likelihood		-4.421			Log-likelihood		-32.057		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		2.64			Anderson-Darling (adjusted)		2.878		
Correlation coefficient		0.982			Correlation coefficient		0.989		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.653782	0.421119	0.184991	2.31055	Mean	1.18024	0.943965	0.246135	5.65936
Standard deviation	1.64306	1.99408	0.152267	17.7297	Standard deviation	2.93744	4.72115	0.12586	68.5566
Median	0.24171	0.118988	0.0921021	0.634339	Median	0.440022	0.228212	0.159225	1.21602
First quartile (Q1)	0.0933392	0.0592101	0.0269216	0.323614	First quartile (Q1)	0.170604	0.122943	0.0415511	0.700477
Third quartile (Q3)	0.625932	0.306129	0.240006	1.63242	Third quartile (Q3)	1.13491	0.618028	0.390328	3.29984
Interquartile range (IQR)	0.532592	0.279416	0.19047	1.48924	Interquartile range (IQR)	0.964306	0.588827	0.291375	3.19138

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Ops*					**OZf**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		3			Uncensored value		8		
Left censored value		7			Left censored value		0		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-4.59511	0.651571	-5.87217	-3.31806	Location	-0.861046	0.430412	-1.70464	-0.0174541
Scale	1.70447	0.0790912	1.55629	1.86675	Scale	1.14421	0.3512	0.626965	2.0882
Log-likelihood		-7.89			Log-likelihood		-6.792		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		1.393			Anderson-Darling (adjusted)		2.89		
Correlation coefficient		0.86			Correlation coefficient		0.986		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.0431743	0.0280004	0.0121111	0.15391	Mean	0.813481	0.388955	0.318682	2.07653
Standard deviation	0.179415	0.121157	0.0477589	0.674006	Standard deviation	1.3375	1.20545	0.228632	7.82445
Median	0.0101011	0.0065816	0.0028168	0.0362231	Median	0.42272	0.181944	0.181838	0.982697
First quartile (Q1)	0.0031995	0.002113	0.0008769	0.0116741	First quartile (Q1)	0.195381	0.108958	0.0654924	0.58287
Third quartile (Q3)	0.0318898	0.0206335	0.0089723	0.113345	Third quartile (Q3)	0.914585	0.379014	0.405954	2.0605
Interquartile range (IQR)	0.0286903	0.0185514	0.0080787	0.101889	Interquartile range (IQR)	0.719205	0.330712	0.292041	1.77117

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
OZm					**OZn**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	10				Uncensored value	30			
Left censored value	0				Left censored value	1			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.655272	0.788995	-2.20167	0.89113	Location	0.0159391	0.258203	-0.490129	0.522007
Scale	2.41324	0.682883	1.3859	4.20212	Scale	1.42905	0.185068	1.1087	1.84197
Log-likelihood	-18.878				Log-likelihood	-62.614			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	2.451				Anderson-Darling (adjusted)	1.108			
Correlation coefficient	0.977				Correlation coefficient	0.973			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	9.55049	15.6289	0.386439	236.032	Mean	2.82083	0.990952	1.41694	5.61568
Standard deviation	175.384	559.999	0.33582	9.16×10^4	Standard deviation	7.30561	4.39151	2.24898	23.7315
Median	0.519301	0.409726	0.110618	2.43788	Median	1.01607	0.262351	0.612547	1.68541
First quartile (Q1)	0.10198	0.102956	0.0140984	0.737666	First quartile (Q1)	0.387538	0.115277	0.21633	0.694244
Third quartile (Q3)	2.64437	2.13213	0.544513	12.8421	Third quartile (Q3)	2.66398	0.734496	1.55182	4.57318
Interquartile range (IQR)	2.54239	2.08213	0.51067	12.6574	Interquartile range (IQR)	2.27644	0.668797	1.27991	4.04884

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
OZnb					**Ph**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		14			Uncensored value		8		
Left censored value		6			Left censored value		1		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-1.75943	0.483527	-2.70713	-0.811735	Location	-1.75943	0.483527	-2.70713	-0.811735
Scale	2.1023	0.305023	1.58196	2.7938	Scale	2.1023	0.305023	1.58196	2.7938
Log-likelihood		-34.212			Log-likelihood		-25.95		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		1.676			Anderson-Darling (adjusted)		2.642		
Correlation coefficient		0.857			Correlation coefficient		0.896		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	1.56895	1.24124	0.332813	7.39637	Mean	91.6336	231.335	0.650347	1.29×10^4
Standard deviation	14.2135	19.3858	0.981158	205.902	Standard deviation	1.04×10^4	5.03×10^4	0.801103	1.35×10^8
Median	0.172143	0.0832357	0.0667283	0.444087	Median	0.806891	0.840909	0.104647	6.2216
First quartile (Q1)	0.0416934	0.0221509	0.0147177	0.118112	First quartile (Q1)	0.101305	0.123643	0.0092627	1.10796
Third quartile (Q3)	0.71074	0.369306	0.256697	1.96789	Third quartile (Q3)	6.42687	7.16985	0.721764	57.2274
Interquartile range (IQR)	0.669046	0.354301	0.236969	1.88895	Interquartile range (IQR)	6.32557	7.09744	0.701505	57.0385

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Sacgr					Sagr				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	53				Uncensored value	10			
Left censored value	0				Left censored value	1			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	0.936261	0.246092	0.45393	1.41859	Location	0.494757	0.780732	-1.03545	2.02496
Scale	1.79023	0.178323	1.47273	2.17619	Scale	2.5312	0.64904	1.53131	4.18396
Log-likelihood	-157.38				Log-likelihood	-36.858			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	1.382				Anderson-Darling (adjusted)	2.278			
Correlation coefficient	0.959				Correlation coefficient	0.969			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	12.6636	5.00803	5.83356	27.4903	Mean	40.3759	68.0789	1.48213	1.10×10^3
Standard deviation	61.5898	42.368	15.9942	237.167	Standard deviation	993.15	3.22×10^3	1.7375	5.68×10^4
Median	2.55043	0.62764	1.57449	4.1313	Median	1.6401	1.28048	0.355067	7.57584
First quartile (Q1)	0.762438	0.212005	0.442097	1.3149	First quartile (Q1)	0.29745	0.286112	0.0451501	1.95961
Third quartile (Q3)	8.53142	2.3009	5.02868	14.474	Third quartile (Q3)	9.04329	7.44166	1.80251	45.3706
Interquartile range (IQR)	7.76898	2.17703	4.4858	13.4551	Interquartile range (IQR)	8.74584	7.29465	1.70545	44.8501

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Sb					**Sbs**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	16				Uncensored value	12			
Left censored value	0				Left censored value	0			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.202141	0.371811	-0.930878	0.526595	Location	-0.518142	0.27691	-1.06087	0.0245912
Scale	1.46215	0.283057	1.00048	2.13686	Scale	0.930099	0.211768	0.595285	1.45323
Log-likelihood	-27.626				Log-likelihood	-11.145			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	1.715				Anderson-Darling (adjusted)	2.019			
Correlation coefficient	0.97				Correlation coefficient	0.994			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	2.37929	1.19732	0.88736	6.3796	Mean	0.917962	0.27353	0.511902	1.64612
Standard deviation	6.50789	5.81329	1.13003	37.4792	Standard deviation	1.07649	0.582141	0.372989	3.10685
Median	0.816979	0.303762	0.394208	1.69316	Median	0.595626	0.164935	0.346153	1.0249
First quartile (Q1)	0.304725	0.136503	0.126651	0.733174	First quartile (Q1)	0.31807	0.108532	0.162958	0.620827
Third quartile (Q3)	2.19036	0.844705	1.02861	4.66421	Third quartile (Q3)	1.11539	0.31097	0.645817	1.92637
Interquartile range (IQR)	1.88563	0.772188	0.845045	4.20759	Interquartile range (IQR)	0.797316	0.261822	0.418903	1.51757

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Se					Sgr				
Censoring information	Count				Censoring information	Count			
Uncensored value	8				Uncensored value	7			
Left censored value	0				Left censored value	0			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					Parameter estimates				
Parameter	Estimate	Standard error	95% normal CI		Parameter	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Location	-0.292614	0.287496	-0.856096	0.270868	Location	-0.822002	0.675265	-2.1455	0.501493
Scale	0.766477	0.228921	0.426849	1.37633	Scale	1.69502	0.788348	0.681216	4.21761
Log-likelihood	-7.605				Log-likelihood	-8.001			
Goodness-of-fit					Goodness-of-fit				
Anderson-Darling (adjusted)	2.986				Anderson-Darling (adjusted)	3.238			
Correlation coefficient	0.963				Correlation coefficient	0.974			
Characteristics of distribution					Characteristics of distribution				
Descriptor	Estimate	Standard error	95% normal CI		Descriptor	Estimate	Standard error	95% normal CI	
			Lower	Upper				Lower	Upper
Mean	1.00113	0.282716	0.57559	1.74128	Mean	1.84882	2.39012	0.146717	23.2976
Standard deviation	0.895135	0.489043	0.306795	2.61174	Standard deviation	7.55348	19.7808	0.0445706	1.28×10^3
Median	0.74631	0.214561	0.424817	1.3111	Median	0.439551	0.296813	0.11701	1.65118
First quartile (Q1)	0.445038	0.164209	0.215935	0.917215	First quartile (Q1)	0.140117	0.137691	0.0204188	0.961507
Third quartile (Q3)	1.25153	0.346937	0.726907	2.15478	Third quartile (Q3)	1.37888	0.986436	0.339304	5.60359
Interquartile range (IQR)	0.806491	0.286032	0.402448	1.61618	Interquartile range (IQR)	1.23877	0.961806	0.270456	5.6739

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
So					**SOagr**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		12			Uncensored value		10		
Left censored value		2			Left censored value		2		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.910549	0.544193	-1.97715	0.156049	Location	-1.84542	0.919828	-3.64825	-0.0425933
Scale	1.99838	0.413305	1.3324	2.99726	Scale	3.01868	0.795339	1.80115	5.05924
Log-likelihood		-25.899			Log-likelihood		-19.087		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		1.719			Anderson-Darling (adjusted)		2.108		
Correlation coefficient		0.968			Correlation coefficient		0.969		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	2.96306	2.75646	0.478508	18.3481	Mean	15.0412	35.1856	0.153493	1.47×10^3
Standard deviation	21.6215	36.4911	0.791215	590.851	Standard deviation	1.43×10^3	6.66×10^3	0.157509	1.30×10^7
Median	0.402303	0.218931	0.138464	1.16888	Median	0.157959	0.145295	0.0260366	0.958301
First quartile (Q1)	0.104513	0.0670819	0.029705	0.367718	First quartile (Q1)	0.02062	0.0242945	0.0020484	0.207574
Third quartile (Q3)	1.54858	0.897307	0.497413	4.82117	Third quartile (Q3)	1.21003	1.13483	0.192528	7.60502
Interquartile range (IQR)	1.44407	0.859624	0.449662	4.63757	Interquartile range (IQR)	1.18941	1.12275	0.186997	7.56538

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
SObo					**Sp**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		6			Uncensored value		17		
Left censored value		1			Left censored value		5		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.077395	1.18885	-2.40749	2.2527	Location	-1.60967	0.664053	-2.91119	-0.308154
Scale	3.01338	1.16867	1.40908	6.44427	Scale	2.9756	0.556342	2.06266	4.29262
Log-likelihood		-21.941			Log-likelihood		-41.869		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		3.218			Anderson-Darling (adjusted)		1.409		
Correlation coefficient		0.982			Correlation coefficient		0.984		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	86.7332	297.632	0.104044	7.23×10^4	Mean	16.7339	27.7695	0.647216	432.658
Standard deviation	8.13×10^3	5.57×10^4	0.0119581	5.52×10^9	Standard deviation	1.40×10^3	4.55×10^3	2.40745	8.14×10^5
Median	0.925524	1.10031	0.0900407	9.51342	Median	0.199953	0.132779	0.0544107	0.734802
First quartile (Q1)	0.121251	0.191379	0.0054977	2.67421	First quartile (Q1)	0.0268715	0.0221378	0.0053461	0.135066
Third quartile (Q3)	7.06462	8.87495	0.602233	82.8731	Third quartile (Q3)	1.48786	1.03601	0.380072	5.82452
Interquartile range (IQR)	6.94337	8.80026	0.579067	83.2552	Interquartile range (IQR)	1.46099	1.0246	0.36957	5.77562

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Spsq*					**Spss**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		4			Uncensored value		7		
Left censored value		5			Left censored value		0		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-3.26786	0.765784	-4.76876	-1.76695	Location	-2.5205	0.796308	-4.08124	-0.959767
Scale	2.09694	0.118607	1.87689	2.34278	Scale	2.09694	0.118607	1.87689	2.34278
Log-likelihood		-11.6			Log-likelihood		-1.372		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		1.645			Anderson-Darling (adjusted)		2.819		
Correlation coefficient		0.948			Correlation coefficient		0.998		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.343254	0.271361	0.0728944	1.61635	Mean	0.724747	0.587722	0.147883	3.55185
Standard deviation	3.07434	2.73261	0.538474	17.5525	Standard deviation	6.49117	5.83285	1.11544	37.7744
Median	0.038088	0.0291672	0.0084909	0.170854	Median	0.0804192	0.0640385	0.0168866	0.382982
First quartile (Q1)	0.0092585	0.0071735	0.0020278	0.0422721	First quartile (Q1)	0.0195484	0.0157948	0.0040119	0.0952511
Third quartile (Q3)	0.156689	0.119878	0.0349793	0.701883	Third quartile (Q3)	0.330833	0.262209	0.0699794	1.56404
Interquartile range (IQR)	0.14743	0.112868	0.0328802	0.661059	Interquartile range (IQR)	0.311285	0.246747	0.0658315	1.47191

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
Ssqd					**St**				
Censoring information	**Count**				**Censoring information**	**Count**			
Uncensored value	10				Uncensored value	14			
Left censored value	1				Left censored value	1			
Distribution	Log normal				Distribution	Log normal			
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-0.977338	0.709125	-2.3672	0.412522	Location	-1.16725	0.499365	-2.14599	-0.188511
Scale	2.23919	0.386238	1.59686	3.13989	Scale	1.88108	0.379981	1.26609	2.7948
Log-likelihood	-26.615				Log-likelihood	-20.191			
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)	2.275				Anderson-Darling (adjusted)	1.712			
Correlation coefficient	0.975				Correlation coefficient	0.985			
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	4.61653	4.38346	0.717942	29.6854	Mean	1.82574	1.42605	0.394987	8.43907
Standard deviation	56.4465	94.6883	2.10744	1.51×10^3	Standard deviation	10.5537	15.1096	0.637893	174.606
Median	0.376312	0.266852	0.093743	1.51062	Median	0.311222	0.155413	0.116953	0.828192
First quartile (Q1)	0.0831052	0.0683251	0.0165887	0.416337	First quartile (Q1)	0.0875086	0.0531504	0.0266105	0.287772
Third quartile (Q3)	1.70399	1.16261	0.447404	6.48982	Third quartile (Q3)	1.10685	0.565689	0.406499	3.01384
Interquartile range (IQR)	1.62088	1.11047	0.423246	6.20742	Interquartile range (IQR)	1.01935	0.535954	0.363726	2.85672

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation									
SZtb					**Zpg**				
Censoring information		**Count**			**Censoring information**		**Count**		
Uncensored value		21			Uncensored value		10		
Left censored value		12			Left censored value		1		
Distribution		Log normal			Distribution		Log normal		
Parameter estimates					**Parameter estimates**				
Parameter	**Estimate**	**Standard error**	**95% normal CI**		**Parameter**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Location	-3.4627	0.477822	-4.39922	-2.52619	Location	-0.005913	0.71992	-1.41693	1.4051
Scale	2.34744	0.380468	1.70857	3.22519	Scale	2.30151	0.483285	1.52501	3.47339
Log-likelihood		-18.676			Log-likelihood		-33.305		
Goodness-of-fit					**Goodness-of-fit**				
Anderson-Darling (adjusted)		1.832			Anderson-Darling (adjusted)		2.335		
Correlation coefficient		0.966			Correlation coefficient		0.958		
Characteristics of distribution					**Characteristics of distribution**				
Descriptor	**Estimate**	**Standard error**	**95% normal CI**		**Descriptor**	**Estimate**	**Standard error**	**95% normal CI**	
			Lower	**Upper**				**Lower**	**Upper**
Mean	0.492893	0.403814	0.0989431	2.45539	Mean	14.0493	16.4147	1.42277	138.73
Standard deviation	7.73496	12.7591	0.305047	196.133	Standard deviation	198.055	429.793	2.81588	1.39×10^4
Median	0.0313449	0.0149773	0.012287	0.0799632	Median	0.994104	0.715676	0.242457	4.07595
First quartile (Q1)	0.0064348	0.0040499	0.0018742	0.0220932	First quartile (Q1)	0.210502	0.180952	0.0390432	1.13492
Third quartile (Q3)	0.152685	0.0669433	0.064654	0.360577	Third quartile (Q3)	4.6947	3.35313	1.15784	19.0357
Interquartile range (IQR)	0.14625	0.0646419	0.0614992	0.347795	Interquartile range (IQR)	4.4842	3.23448	1.09071	18.4358

Appendix 6. Uranium log-normal fit statistics by bedrock unit.—Continued

[CI, confidence interval; %, percent; *, fewer than five analyses were above the analytical reporting limit and the Minitab option to assume a common scale was used in the distribution fitting]

Bedrock unit abbreviation				
Zsg				
Censoring information	Count			
Uncensored value	23			
Left censored value	0			
Distribution	Log normal			
Parameter estimates				
Parameter	Estimate	Standard error	95% normal CI	
			Lower	Upper
Location	1.80621	0.268843	1.27929	2.33314
Scale	1.2783	0.201315	0.938816	1.74055
Log-likelihood	-81.557			
Goodness-of-fit				
Anderson-Darling (adjusted)	1.276			
Correlation coefficient	0.989			
Characteristics of distribution				
Descriptor	Estimate	Standard error	95% normal CI	
			Lower	Upper
Mean	13.7803	4.78246	6.97989	27.2062
Standard deviation	27.9866	16.9035	8.56714	91.4248
Median	6.08735	1.63654	3.59408	10.3102
First quartile (Q1)	2.57027	0.813775	1.38191	4.78056
Third quartile (Q3)	14.4171	4.10789	8.24788	25.2007
Interquartile range (IQR)	11.8468	3.68061	6.44387	21.7799

Prepared by the Pembroke and the Ft. Lauderdale
Publishing Service Centers

For more information concerning this report, contact:

Director
U.S. Geological Survey
Massachusetts-Rhode Island Water Science Center
10 Bearfoot Road
Northborough, MA 01532
dc_ma@usgs.gov

or visit our Web site at:
http://ma.water.usgs.gov

Colman—**Arsenic and Uranium in Water from Private Wells Completed in Bedrock of East-Central Massachusetts**—SIR 2011–5013
—Concentrations, Correlations with Bedrock Units, and Estimated Probability Maps

ISBN 978-1-4113-3100-6