Characteristics of and Areas Contributing Recharge to Public-Supply Springs in Massachusetts

By Bruce P. Hansen and Kirk P. Smith

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CONVERSION FACTORS, VERTICAL AND HORIZONTAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
inch per year (in/yr)	25.4	millimeter per year (km/yr)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

mho/m	mho per meter
µg/L	micrograms per liter

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Abstract

The geohydrologic and physical characteristics were determined for 28 public-supply springs, 27 of which are in western Massachusetts. Discharge ranged from zero at various small intermittent springs to more than 240 gallons per minute at Waubeeka Springs in Williamstown, Massachusetts. To determine the annual variability of spring discharge, discharge from 12 springs was measured during different seasonal conditions from June 2001 to November 2002, and the discharge from Red Mill Spring in Clarksburg, Massachusetts was recorded continuously from April 2002 to November 2002. The area contributing recharge to each spring was delineated on the basis of the geohydrologic conditions determined from reconnaissance investigations; these areas ranged from 0.010 to 0.682 square mile. Ground-water recharge, estimated on the basis of average discharge and the areas contributing recharge, ranged from 0.5 to 24.4 inches per year. High ground-water recharge rates for some of the high-discharge springs indicate that the areas contributing recharge for these springs may be too small. Detailed water-table mapping in the vicinity of two low-discharge springs indicates that the area contributing recharge to some of the smaller springs may be smaller than the area indicated by reconnaissance investigation.

In the carbonate geologic terrane of Western Massachusetts, many of the springs, and especially the larger springs, are located on top of, or in close proximity to, major geologic features such as thrust faults and sinkholes. This proximity indicates that the location and high yields of some springs in this area are affected by the bedrock lithology and structure.

Introduction

The Massachusetts Department of Environmental Protection (MADEP) is responsible for promulgating public-health-protection regulations for all public-water-supply sources in Massachusetts. A public-supply spring is defined in MADEP regulations as "a natural discharge point where ground water issues from soils or rock in concentrated flow. Public-water-supply springs must be perennial and of non-thermal origin. A source is not considered a spring if mechanical methods are used to induce the flow of water. The collection system must not hydraulically affect the water table." (Massachusetts Department of Environmental Protection, 1996, Section 4.2.4, p. 69).

The source-protection regulations currently (2002) in place for springs are loosely based on public-supply-well regulations that assume radial flow to the source. Public-supply springs are assigned a default Zone 1 (Zone 1 Protection Area) that the supplier must own or control. The size of the Zone 1 is based on the average discharge during high-flow conditions. For example, a flow rate of 5 gal/min or 7,200 gal/d requires a square protection area that is 457 ft on a side. The minimum required area is a 200-ft square (0.7 gal/min or less) and the maximum is a 800-ft square (70 gal/min or more). The square is aligned in the direction of the hydraulic gradient with the spring centered on and 50 ft upgradient from the downgradient side of the square, regardless of the size of the square or the magnitude of the hydraulic gradient. Public-water-supply springs are also assigned a larger circular Interim Wellhead Protection Area (IWPA), a legally defined recharge area within which the MADEP may impose controls to protect public health. The IWPA is defined for springs and for wells as a circle whose radius is based on maximum daily yield. For a spring with a yield of 100,000 gal/d, the IWPA would be a circle with a radius of 2,640 ft. These criteria are reasonable for supply wells because of the hydraulic stress produced by pumping but are inappropriate for establishing effective protection areas for springs. The area contributing water to a spring is located upgradient of the spring within the local hydrologic framework. A hydrologic approach could be used to define the flow regime at springs more accurately. This approach would account for the unique combination of physical, hydraulic, and geological conditions at each site.

The MADEP currently requires extensive documentation for approval of new public-supply springs (Massachusetts Department of Environmental Protection, 1996); the documentation includes the delineation of both a Zone 1 and IWPA based on spring discharge measured during high-flow periods. Because it was not previously required, little of the presently required information has been collected and even less of the geohydrologic information needed to delineate the area contributing recharge to existing public-water-supply springs in Massachusetts more accurately. The U.S. Geological Survey (USGS), in cooperation with the MADEP, conducted an investigation of existing public-supply springs during the years 2001 to 2003 with two objectives. The first objective of the investigation was to characterize each spring, including its location, type, principal aquifer (defined as the geologic material from which water discharges), hydrogeologic framework, discharge, improvement structures, and use. The second objective was to delineate the area contributing recharge to each spring. The areas contributing recharge were compared to the Zone 1s as defined by MADEP regulations.

The purpose of this report is to present the methods used in this investigation, descriptions of the physical and hydrogeologic characteristics of all existing public-supply springs, and maps showing the delineated areas contributing recharge. Results of more detailed investigations of the configuration of the water table adjacent to two spring sites are also presented.

The authors thank Bruce Bouck and Paul Blain of the MADEP for providing current and historical spring data, field assistance, and guidance for the direction of the investigation. We also appreciate the cooperation of the many spring owners and operators who gave their time to provide access and assistance and who provided invaluable information about present and historical spring conditions.

Methods of Investigation

Background information was assembled from USGS and MADEP files, and from published and unpublished maps and reports describing bedrock and surficial geology and surficial materials in the vicinity of the springs. MADEP and USGS personnel visited each of the 31 springs listed as public-supply springs in the MADEP database. Some of these springs are composed of multiple seepage or discharge points with multiple collection structures. During the visit, the coordinates of the spring and related structures were determined by means of a global positioning system (GPS). The topographic and hydrologic setting and spring type were observed and recorded. Geologic conditions, including the type of surficial materials, location of bedrock outcrops, and orientation of bedrock fractures were recorded. Pictures were taken of the spring, collection and other related structures, and the surrounding area. Sketches were drawn showing the location and size of improvement structures such as cisterns, collection basins, and plumbing. Discharge was measured by volumetric methods at sites where the improvement structures and plumbing made this possible. Spring owners and operators were interviewed to collect current and historical spring information.

On the basis of the data collected during the site visits, MADEP determined that three sources did not meet their definition of a spring because improvement structures lowered the water level below natural levels to induce greater than natural flow. These sources were removed from the list of public-supply springs. The locations and characteristics of the remaining 28 public-supply springs are shown in figure 1 (at back of report) and table 1.

All of the springs observed during this study are gravity springs that result from ground water flowing under hydrostatic pressure. They were classified into the following types of springs:

1. Seepage spring—discharge of water where the ground surface intersects the water table in an unconsolidated aquifer and no mitigating factors were observed.
2. Contact spring—discharge of water where a low-permeability deposit, such as bedrock, outcrops at the land surface beneath more permeable and saturated overlying deposits, such as till or sand and gravel; water flows onto the land surface at the contact between the bedrock and overlying unconsolidated deposits.
3. Fracture spring— discharge of water directly from a fracture in bedrock.
4. Tubular spring—discharge of water from a fracture that has been enlarged by the solution of rock material.
5. Artesian spring—discharge of water resulting from the release of ground water under pressure in a confined aquifer through an opening in the confining layer or at an outcrop of the aquifer.

To determine the variability of spring discharge under different hydrogeologic and seasonal conditions, instantaneous discharge was measured at 16 springs (fig. 1, numbers 1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23, 24) during different seasonal conditions from June 2001 to November 2002 (table 2). A weir with a recording discharge gage was installed at Red Mill Spring (fig. 1, number 3); discharge was recorded electronically every 15 minutes. For springs with discharge measurements spanning more than a year, variability of spring flow, defined by Meinzer (1923) as the ratio of discharge fluctuation to the average discharge within a given period of record, was determined by applying the equation

$$V = 100\frac{(a-b)}{c},$$

where

V is variability, in percent;
a is the maximum discharge;
b is the minimum discharge; and
c is the average spring discharge.

Variability of spring flow and average discharge are shown in table 2.

Table 1. Characteristics of public-supply springs in Massachusetts.

[**Map No.:** Number shown on figure 1. **Latitude and longitude**: In degrees, minutes, and seconds. Determined by geographic positioning system referenced to North American datum of 1983. **Altitude:** Determined from USGS 1:25,000 quadrangle maps and referenced to North American vertical datum of 1929. **Water use:** C, commercial; D, domestic; I, irrigation; P, public supply; S, stock; U, unused. **Spring type:** A, artesian; C, contact; F, fracture; S, seep; T, tubular. **Principal aquifer:** D, dolomite; F, very near mapped thrust fault; G, gneiss; Q, metaquartzite; SG, sand and gravel; SH, schist; SS, sandstone; T, till: UN, unconsolidated-undifferentiated deposits. **Remarks:** diam., diameter; I, intermittent flow; P, perennial flow; Rte., Route; V, spring-flow variability in percent (Meinzer, 1923). MADEP, Massachusetts Department of Environmental Protection; USGS, U.S. Geological Survey; WFD, Worthington Fire District. ft, foot; % percent]

Map number	Spring name	USGS local No.	MADEP source number	Town	Latitude ° ′ ″	Longitude ° ′ ″	Altitude (ft)
Public-supply springs							
1	Becket Spring	MA-A3S 1	1022001-01G	Becket	42 16 14.25	73 00 06.65	823
2	New Belden Tavern Spring	MA-A3S 2	1150013-01G	Becket	42 17 46.02	73 09 36.17	1,624
3	Red Mill Spring	MA-COS 1	1063003-01G	Clarksburg	42 43 00.79	73 04 23.47	1,030
4	Fanny Rogers Spring	MA-CYS 1	1069001-04G	Cummington	42 27 21.28	72 54 43.49	1,420
5	Keats Spring	MA-DFS 10	1074000-02G	Deerfield	42 32 22.66	72 35 12.25	580
6	Wells Spring	MA-DFS 11	1074000-03G	Deerfield	42 32 36.75	72 35 26.88	419
7	Harris Spring	MA-DFS 13	1074000-04G	Deerfield	42 31 04.04	72 37 56.22	196
8	Stillwater Spring	MA-DFS 12	1074000-06G	Deerfield	42 31 30.72	72 38 03.89	232
9	Guilder Hills Spring	MA-EOS 1	1090008-01G	Egremont	42 08 36.78	73 27 11.01	930
10	Whitcomb Summit Spring	MA-FUS 1	1098005-01G	Florida	42 41 17.25	73 00 50.33	1,834
11	Granville Center Spring	MA-GLS 1	1112000-01G	Granville	42 04 41.3	72 53 17.5	1,138
12	Mt. Blue Spring	MA-HOS 1	3131001-01G	Hingham	42 11 58.25	70 05 34.90	107
13	Berkshire Spring	MA-LMS 1	1148015-01G	Lanesborough	42 30 33.46	73 11 52.52	980
14	Cold Spring	MA-LOS 2	1150002-01G	Lee	42 17 05.38	73 14 20.35	895
15	Mill River Road Spring 1	MA-NKS 6	1150002-01G	New Marlborough	42 06 34.79	73 15 48.65	890
16	Mill River Road Spring 2	MA-NKS 10	1203000-02G	New Marlborough	42 06 34.28	73 15 49.55	875
17	Peru Roadside Spring	MA-PGS 1	1233003-01G	Peru	42 25 59.86	73 01 25.85	1,860
18	Farm House Spring	MA-SJS 3	1267000-01G	Sheffield	42 07 33.50	73 19 35.30	780
19	Red Rock Spring	MA-SJS 2	1267000-02G	Sheffield	42 07 38.28	73 19 29.12	885
20	Barrel Spring	MA-SJS 4	1267000-06G	Sheffield	42 07 36.30	73 19 28.73	856
21	Smith Spring	MA-SJS 1	1267000-03G	Sheffield	42 07 46.19	73 19 42.18	775
22	Goulds Sugarhouse Spring	MA SKW 3	1268002-01G	Shelburne	42 35 07.81	72 42 33.01	590
23	High Lawn Farm Spring	MA-SZS 2	1150003-01G	Stockbridge	42 19 11.9	73 17 55.0	967
24	Waubeeka Springs	MA-XLS 6A	1341004-01G	Williamstown	42 38 38.51	73 14 33.08	1,069
		MA-XLS 6B			42 38 38.73	73 14 30.08	1,066
25	WFD Spring 1	MA-XTS 1	1349000-05G	Worthington	42 25 05.63	72 56 58.99	1,692
26	WFD Spring 2	MA-XTS 2	1349000-06G	Worthington	42 25 09.30	72 57 02.66	1,716
27	WFD Spring 3	MA-XTS 3	1349000-07G	Worthington	42 25 10.30	72 57 03.55	1,725
28	WFD Spring 4	MA-XTS 4	1349000-08G	Worthington	42 25 13.94	72 56 55.90	1,663
Study site							
12	Mt. Blue Spring	MA-HOS 1	3131001-01G	Hingham	42 11 58.25	70 05 34.90	107
29	Silver Brook Café Spring	MA-SCS 1	--	Sandisfield	42 06 05	73 05 51	892

Table 1. Characteristics of public-supply springs in Massachusetts.—Continued

[**Map No.:** Number shown on figure 1.**Latitude and longitude**: In degrees, minutes, and seconds. Determined by geographic positioning system referenced to North American datum of 1983. **Altitude:** Determined from USGS 1:25,000 quadrangle maps and referenced to North American vertical datum of 1929. **Water use:** C, commercial; D, domestic; I, irrigation; P, public supply; S, stock; U, unused. **Spring type:** A, artesian; C, contact; F, fracture; S, seep; T, tubular. **Principal aquifer:** D, dolomite; F, very near mapped thrust fault; G, gneiss; Q, metaquartzite; SG, sand and gravel; SH, schist; SS, sandstone; T, till: UN, unconsolidated-undifferentiated deposits. **Remarks:** diam., diameter; I, intermittent flow; P, perennial flow; Rte., Route; V, spring-flow variability in percent (Meinzer, 1923). MADEP, Massachusetts Department of Environmental Protection; USGS, U.S. Geological Survey; WFD, Worthington Fire District. ft, foot; % percent]

Map number	Owner	Water use	Spring type	Principal aquifer	Remarks
			Public-supply springs		
1	Town of Becket	P	C	SG, T	Route 20 roadside spring, P, V=68%.
2	John Economou	P, C, D	C, F?	T, G, F?	Restaurant and several homes in Lee, P, V=70%.
3	Briggsville Water Department	P, I	F, C	SH	P, V=50%.
4	Cummington Water Department	P	F, C, S	SH, T	3 collection structures, P.
5	Deerfield Fire District	P	S	UN	8-ft-diameter, 10-ft-deep, stone-lined collection gallery, I.
6	Deerfield Fire District	P	F	SS	I.
7	Deerfield Fire District	P	C, S	SG	5 collection structures along base of scarp, P.
8	Deerfield Fire District	P	C, S	SG	17 collection structures along base of scarp (8 in use), P.
9	Guilder Hills Water System	P	C, F	UN, D	P, V=10%.
10	Whitcomb Summit Motel	P, C	C, F	T, SH	P, V=11%.
11	Granville Center Water Company	U, P	C, F	T, SH	Discharge plugged (10/22/01).
12	MA Department of Environmental Management	P	A, C	SG	Roadside spring, Wompatuck State Park, P, V=69%.
13	Town of Lanesborough	P, D	F, T?	D, F?	Roadside spring, pumped community supply, P.
14	Mildred Holmes	P	C, F?	T, Q, D?, F	Roadside spring, P, V=149%.
15	Mill River Water Takers Association	P	S	SG	3-ft-diam. cement pipe, P.
16	Mill River Water Takers Association	P	C, S	SG	23-by-18-ft cement basin, P.
17	Town of Peru	P	C, F?	T, F?	Route 143 roadside spring, P, V=37%.
18	Sheffield Water Company	P	C, S	T	P.
19	Sheffield Water Company	P	F	Q, F	P.
20	Sheffield Water Company	P	S, F	T, G	P.
21	Sheffield Water Company	P	C, F	T, D, F?	P.
22	Gould’s Sugarhouse	P, C	C, S	SG	P.
23	High Lawn Farm	P, C, S, D	T	D, F	All use in Lee, P.
24	Waubeeka Springs Deeded Users	P	C, F	UN, D?	P, V=166%.
25	Worthington Fire District	P	C, S, F?	T, F?	Located adjacent to bedrock well, I.
26	Worthington Fire District	P	C, S, F?	T, F?	I.
27	Worthington Fire District	P	C, S, F?	T, F?	I.
28	Worthington Fire District	U, P	C, S, F?	T, F?	I.
			Study site		
12	MA Department of Environmental Management	P	A, C	SG	Roadside spring, Wompatuck State Park, P, V=69%.
29	Silver Brook Café	U	C, S	SG	Located adjacent to well used for commercial and domestic supply.

Table 2. Measured discharge of public-supply springs in Massachusetts, June 2001–November 2002.

[**Remarks:** C, conductance; T, temperature. A, average measured discharge in gallons per minute; V, spring flow variability in percent (Meinzer, 1923). °C, degree Celsius; gal/min, gallons per minute; µS/cm, microsiemens per centimeter at 25 degrees Celsius; %, percent; +, or more; --, no data]

Date	Discharge (gal/min)	Remarks
1. Becket Spring (total) A=6.3 gal/min, V=97%		
8-20-01	10.1	
11-14-01	8.3	
1-15-02	6.4	
2-06-02	5.9	
5-14-02	5.2	
7-22-02	4.3	
9-22-02	4.0	
1. Becket Spring (supply pipe) A= 2.1 gal/min		
8-20-01	--	
11-14-01	2.7	
1-15-02	2.0	
2-06-02	1.8	T=7.0°C, C=83 µS/cm.
5-14-02	2.2	
7-22-02	2.0	
9-22-02	2.0	
2. New Belden Tavern Spring A=2.3 gal/min, V=70%		
1-16-02	3.2	
2-06-02	2.1	
4-25-02	3.2	
5-30-02	1.8	
7-22-02	1.6	
9-10-02	2.0	
3. Red Mill Spring A=185 gal/min, V=50%		
8-07-01	[1]144	golf course pump on.
11-13-01	[1]132	golf course pump off.
1-15-02	[1]142	golf course pump off.
2-07-02	--	golf course pump off, T=7.1°C, C=152 µS/cm.
4-24-02	[1]172	golf course pump off, recorder installed.
4-25-02	[1]175	golf course pump off.
5-14-02	[1]159	golf course pump off.
5-30-02	[1]159	golf course pump off.
9-10-02	[1]144	golf course pump on.
11-14-02	[1]174	golf course pump off.
4. Fanny Rogers Springs		
8-20-01	[2]2	
7. and 8. Harris and Stillwater Spring		
8-02-01	84.5	
11-13-01	31.4	
1-15-02	21.2	
9. Guilder Hills Spring A=14.3 gal/min, V=10%		
10-03-01	15.0	
11-14-01	13.6	
1-16-02	13.6	
7-22-02	15.0	
10. Whitcomb Summit Spring A=13.3 gal/min, V=11%		
8-07-01	13.8	
11-13-01	12.5	
1-15-02	13.0	
4-24-02	14.0	T=6.8°C, C=151 µS/cm.
11. Granville Center Spring		
10-22-01	--	Discharge line plugged.
12. Mount Blue Spring A=3.6 gal/min, V=69%		
6-26-01	5.0	
7-20-01	3.8	
11-15-01	2.5	
1-03-01	3.0	
3-07-02	4.3	
8-12-02	3.2	
13. Berkshire Spring		
2-07-02	[3]50–60+	
14. Cold Spring A=14.1gal/min, V=149%		
7-25-01	[4]15.0	
10-03-01	[4]11.3	
11-14-01	[4]7.9	
1-15-02	[4]7.1	
2-06-02	[4]7.3	
4-25-02	[4]21.4	
5-30-02	[4]28.1	
7-22-02	[4]17.8	
9-10-02	[4]10.9	
15 and 16. Mill River Road Springs 1 and 2		
10-30-01	[1]2.7	Combined discharge.
8-07-02	[1]2.4	Combined discharge.
17. Peru Roadside Spring A=1.03 gal/min, V=37%		
8-03-01	1.0	
9-20-01	0.9	
11-14-01	1.01	
11-15-02	1.02	
2-06-02	1.02	T=7.4°C, C=76 µS/cm.

Table 2. Measured discharge of public-supply springs in Massachusetts, June 2001–November 2002.—*Continued*

Date	Discharge (gal/min)	Remarks
17. Peru Roadside Spring A=1.03 gal/min, V=37%—Continued		
5-14-02	1.28	
7-22-02	0.98	
22. Goulds Sugar House Spring		
6-28-01	1.2	
23. High Lawn Farm Spring		
8-02-02	47	
24. Waubeeka Springs A=114.8 gal/min, V=166%		
8-08-01	[5]100	
11-30-01	[5]49	
1-15-02	[5]70	
4-24-02	[5]240	

[1] Reservoir overflow and uncollected spring discharge measured in culvert under road; does not include discharge to water-supply system and golf course when pump running. Total spring discharge is larger than value shown.

[2] Discharge from reservoir after flowing for 2 hours; discharge adjusted to hold water level in reservoir constant.

[3] Some flow components measured, some estimated.

[4] Total spring discharge through culvert under road.

[5] Spring discharge minus flow to water-supply system.

To assist in the assessment of the source of spring water, water-quality samples were collected from Red Mill, Berkshire, and Cold Springs (fig. 1, numbers 3, 12, and 13). Samples were also collected from streams that appeared to be potential sources of discharge to Red Mill and Berkshire Springs in order to compare the water quality. The USGS National Water-Quality Laboratory analyzed the water samples for inorganic constituents and nutrients. The results of the water-quality analysis are shown in table 3.

In this report, the "area contributing recharge to a discharging spring," or the shorter term "area contributing recharge," is defined as the surface area on the three-dimensional boundary of the ground-water system that delineates the location of the water entering the ground-water system that eventually flows to the spring and discharges (modified from Reilly and Pollock, 1993). In some geohydrologic settings, not all of the water entering the ground-water system within this area discharges from the spring. For example, some ground-water recharge may discharge from the area as underflow. The area contributing recharge for each spring was delineated by integrating a variety of data, such as topographic setting, geologic controls, ground-water and surface-water altitudes, magnitude and variability of discharge, and by using scientific judgment in data interpretation. In general, the first step was constructing a conceptual water-table map of the vicinity of each spring. The water-table contours were assumed to conform, in a subdued way, to the topography of each area and were affected by the altitudes of streams, swamps, and ponds. In some cases, the crest of the water table does not coincide with the topographic high but is representative of the topographic features' overall shape and center of mass. Each area contributing recharge was constructed by drawing ground-water-flow lines on the water-table map from the spring discharge point upgradient to a ground-water divide. Other factors, such as geologic lithology and structure, were used to adjust the size and the shape of the area contributing recharge. Some of these factors were especially important for high-discharge springs in areas with carbonate bedrock. The ground-water recharge rate required to support the average discharge (table 2) of each spring was calculated for each area contributing recharge (table 4). These estimated recharge rates range from 0.5 to 24.4 in/yr.

A MADEP Zone 1 Protective Area was delineated for each spring by using the maximum measured (table 2), recorded, reported, or estimated discharge (table 4). The Zone 1 area is defined in the MADEP guidelines (Massachusetts Department of Environmental Protection, 1996) as a square around the spring that is oriented in the direction of ground-water flow with the spring centered inside the square 50 ft from the downgradient side. The square has a minimum size of 200 ft and a maximum of 800 ft on a side; these sizes correspond to discharge rates of 0.7 gal/min or less and 70 gal/min or more. For a spring discharge rate between the minimum and maximum, the size of the Zone 1 square is determined by the equation

$$\begin{gathered}\text{Zone 1 square, in feet} = \\ 2 \times [(150 \times \text{log of the maximum spring} \\ \text{discharge, in gal/d}) - 350].\end{gathered}$$

Table 3. Physical properties and concentrations of major inorganic constituents and nutrients in spring water and in water from nearby streams, in western Massachusetts, April 2002.

[E, estimated; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; <, actual value is less than value shown]

Date	Station name	Station number	pH, whole water, field (standard units)	Specific conductance, field (µS/cm at 25°C)	Hardness, total (mg/L as CaCo$_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
4-24-02	Red Mill Spring[1]	424300073042301	8.3	150	65	14.6	7.04
4-24-02	Hudson Brook at Middle Road, Clarksburg, MA[2]	01331960	7.8	278	51	14.2	3.81
4-25-02	Berkshire Spring[3]	423033073115201	8.1	280	140	32.6	13.2
4-25-02	Hoosic River at Berkshire Pond Dam near Lanesborough, MA[4]	01331340	8.8	386	140	35.1	13.2
4-25-02	Cold Spring[5]	421705073142001	7.1	150	72	16.7	7.35

Date	Station name	Station number	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Alkalinity, dissolved (mg/L as CaCo$_3$)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as So$_4$)
4-24-02	Red Mill Spring[1]	424300073042301	1.28	2.84	72	1.41	3.1
4-24-02	Hudson Brook at Middle Road, Clarksburg, MA[2]	01331960	1.1	28.1	25	63.0	5.1
4-25-02	Berkshire Spring[3]	423033073115201	1.07	2.04	138	3.14	4.5
4-25-02	Hoosic River at Berkshire Pond Dam near Lanesborough, MA[4]	01331340	1.08	21	137	37.1	5.9
4-25-02	Cold Spring[5]	421705073142001	1.13	1.26	67	1.59	9.8

Date	Station name	Station number	Sum of solids, dissolved (mg/L)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Nitrogen, NO$_2$ + NO$_3$ dissolved (mg/L as N)	Phosphorus, total (mg/L as P)
4-24-02	Red Mill Spring[1]	424300073042301	74	<0.04	<0.10	0.15	<0.06
4-24-02	Hudson Brook at Middle Road, Clarksburg, MA[2]	01331960	131	<.04	.09E	.18	<.06
4-25-02	Berkshire Spring[3]	423033073115201	142	<.04	<.10	.54	<.06
4-25-02	Hoosic River at Berkshire Pond Dam near Lanesborough, MA[4]	01331340	196	<.04	.39	<.05	<.06
4-25-02	Cold Spring[5]	421705073142001	78	<.04	<.10	.04E	<.06

[1] Location shown on figure 1 as map No. 3.

[2] Location shown on figure 6.

[3] Location shown on figure 1 as map No. 13.

[4] Location shown on figure 25.

[5] Location shown on figure 1 as map No. 14.

Table 4. Areas contributing recharge, estimated ground-water recharge rates, and Massachusetts Department of Environmental Protection Zone 1 Protection Areas for public-supply springs in Massachusetts.

[**Map No.:** Number shown on figure 1. **Discharge used to calculate MADEP Zone 1 protection area:** e, estimated; m, measured; r, reported. MADEP, Massachusetts Department of Environmental Protection; WFD, Worthington Fire District; ft, foot; gal/min, gallons per minute; in/yr, inches per year; mi^2, square miles; >, actual value is greater than value shown; +, plus; --, data unavailable or of poor quality]

Map number	Spring name	Size of area contributing recharge (mi^2)	Estimated ground-water recharge rate (in/yr)	Size of MADEP Zone 1 protection area square (ft)	Discharge used to calculate MADEP Zone 1 protection area (gal/min)
1	Becket Spring	0.020	9.0	550	10.1 m
2	New Belden Tavern Spring	.140	.5	400	3.2 m
3	Red Mill Spring	.322	16.4	800	240 m
4	Fanny Rogers Spring	.170	--	518	8 m+e
5	Keats Spring	.063	--	344	2.1 e
6	Wells Spring	.078	--	344	2.1 e
7	Harris Spring	.115	[1]8.4	805	42 m
8	Stillwater Spring	.050		950	42 m
9	Guilder Hills Spring	.054	7.9	600	15 m
10	Whitcomb Summit Spring	.032	12.7	590	14.0 m
11	Granville Center Spring	.012	--	340	2.0 e
12	Mt. Blue Spring	.020	5.8	457	5.0 m
13	Berkshire Spring	.152	12.0	800	>50 m+e
14	Cold Spring	.047	9.1	682	28.1 m
15	Mill River Road Spring 1	.086	--	376	>2.7 m+e
16	Mill River Road Spring 2	.086	--	376	>2.7 m+e
17	Peru Roadside Spring	.013	2.4	280	1.3 m
18	Farm House Spring	.056	--	468	5.4 e
19	Red Rock Spring	.056	--	376	2.7 e
20	Barrel Spring	.056	--	376	2.7 e
21	Smith Spring	.056	--	468	5.4 e
22	Goulds Sugarhouse Spring	.013	2.9	272	1.2 m
23	High Lawn Farm Spring	.682	2.9	800	80 r
24	Waubeeka Springs	.141	24.4	800 800	240 m
25	WFD Spring 1	.010	--	292	1.4 e
26, 27	WFD Springs 2 and 3	.010	--	292 292	1.4 e 1.4 e
28	WFD Spring 4	.094	--	292	1.4 e

[1] Based on combined discharge and recharge area for both springs.

Characteristics of and Areas Contributing Recharge to Public-Supply Springs

All but one spring investigated is in the western part of Massachusetts. Several seepage and fracture springs yield only small quantities of water and a few are dry during part of the year. The peak discharge of several tubular and fracture springs exceeds 200 gal/min; these discharges are among the largest in the Commonwealth. Many springs are at the topographic break in slope between steep uplands and less steep lowland areas. Several are adjacent or on top of thrust faults or geologic contacts between carbonate and non-carbonate bedrock. Readers interested in an introductory overview description of the complex geologic setting and geologic history of Massachusetts can consult the book "Roadside Geology of Massachusetts" by James Skehan (2001).

The description of each spring includes location; topographic, geologic, and hydraulic setting; improvement structures; and factors influencing estimation of the area contributing recharge. Spring locations, estimated areas contributing recharge, and the MADEP Zone1 area are shown on maps.

Becket Spring

Becket Spring is located in Becket, MA, about 50 ft north of Route 20 and about 150 ft west of the Chester, MA, town line (figs. 1 and 2, at back of report, table 1). During this study, the total discharge varied from 4.0 to 10.1 gal/min (table 2). Topographically, the spring is located near the base of the steeply incised valley of Walker Brook. This contact spring issues from the base of a small ice-contact terrace deposit composed of boulders and poorly sorted sand and gravel. Rowe Schist, composed of fine-to-medium-grained quartz-muscovite-chlorite schist, underlies the site at shallow depth (Norton, 1974a) and crops out about 100 ft north and south of the site along Route 20. The bedrock structure generally strikes north-south and dips steeply east. A thrust fault is located about 200 ft north of the site (Norton, 1974a).

A highway crew removing unconsolidated material for road repair is reported to have unintentionally created this spring. Their excavation of material intercepted the water table and water began to flow onto the land surface. Improvements at the spring consist of one or two pipes (during some visits there was one pipe, and during others there were two) that are driven into the base of the terrace and from which water flows (fig. 3, at back of report). The spring is used by many people who drive to the location to collect water. This spring is referred to as a "roadside spring," one of several springs available for public use and located adjacent or close to roads.

The area contributing recharge to the spring is estimated to be 0.020 mi^2 and the MADEP Zone 1 is a 550-ft square (fig.2). An estimated 9.0 in/yr of ground-water recharge is required to maintain average spring flow (table 4).

New Belden Tavern Spring

New Belden Tavern Spring in Becket, MA, is about 100 ft north of Becket Road and 90 ft east of the town line between Becket and Lee, MA (figs. 1 and 4, at back of report, table 1). During the study, measured discharge ranged from 1.6 to 3.2 gal/min (table 2). The only improvement consists of a covered 4-ft-square collection basin (fig. 5, at back of report). From the collection basin, discharge is piped, by gravity, about 950 ft downslope to a large buried concrete storage reservoir. From the storage reservoir the water is piped, by gravity, about 975 ft downslope to supply the Belden Tavern and two houses located adjacent to Route 20.

The spring is a contact spring and discharges from under a large boulder (fig. 5) at the bottom of a gentle west-sloping swale. The site is underlain by Lee Gneiss (Ratcliffe, 1985) that is covered by a generally thin layer of boulder till. A thrust fault that separates the Lee Gneiss from the Tyringham Gneiss (Ratcliffe, 1985) is about 150 ft northwest of the site but probably has no effect on the spring.

The area contributing recharge to the spring is estimated to be 0.140 mi^2 and the MADEP Zone 1 is a 400-ft square (fig. 2). The estimated 0.5-in/yr ground-water-recharge rate indicates that the area contributing recharge may be smaller than shown. Ground-water recharge to till probably ranges from 5 to15 in/yr. The recharge area for this spring may only extend about 1,100 ft upgradient instead of the 4,300 ft shown on figure 4. Spring discharge probably does not account for all of the discharge from the recharge area, however; the upslope area of Becket Mountain was included in the recharge area because surface runoff from this upslope area may recharge unconsolidated terrace deposits located on the flat area 1,000 to 1,800 ft upgradient (northeast) of the spring.

Red Mill Spring

Red Mill Spring in Clarksburg, MA, is one of the largest (discharge) springs in Massachusetts. It is 75 ft southeast of Route 8 and 0.92 road mile north of the town line between North Adams and Clarksburg (figs. 1 and 6, at back of report, table 1). The spring discharges at the base of a steep ridge that separates Canyon Brook from the North Branch Hoosic River (figs. 6 and 7, at back of report).

Improvement structures include two concrete collection cisterns (upper right in figure 7*A*) buried in the area where the original natural discharge onto the land surface was largest. From the cisterns, ground-water discharge flows by gravity into a 3,000-gal concrete storage tank (center left in figure 7*A*). The storage tank feeds the Briggsville Water District distribution system, which has 53 connections and supplies about 180 people (Clebe Scott, Spring Operator, oral commun., 2001). The tank also feeds a public water-collection trough that serves a large number of transient users (cover picture). The discharge from the tank overflow and uncollected seepage from the spring area combine to produce a flow of 150 gal/min or more through a culvert under Route 8. This overflow is partially used by the North Adams Country Club, which pumps some of the water for irrigation.

Volumetric measurements of the total overflow discharge through a culvert under Route 8 ranged from 132 to 175 gal/min and are listed in table 2. These discharge measurements did not include water usage. To determine the daily and seasonal variability in spring flow, a recording gage was installed in the culvert under Route 8 (figs. 7*B* and 7*C*) and was operated from April to November 2002. The gage recorded the water depth behind a calibrated weir every 15 min. Discharge was calculated from these data. Figure 8 (at back of report) shows the discharge record from June 7 to June 11, 2002. The graph indicates that maximum daily discharge generally occurs between 12 midnight and 4 a.m. when water use is at a minimum. Discharge recorded during this night-time period is probably close to the actual continuous spring discharge. Several anomalously high discharges on the record of daily maximum overflow discharge (fig. 9, at back of report) are probably the result of additional runoff during periods of heavy precipitation. Disregarding these spikes, the daily maximum spring discharge for the period of record (fig. 9) ranged from about 150 to 240 gal/min. The seasonal trend in flow is evident in this record. In general, discharge observed in April to May increased to a maximum recorded discharge in late June as a result of several periods of heavy precipitation in May and June. Flow slowly declined from July through early September. From late September through early November, flow slowly increased as a result of several periods of heavy precipitation in September and October.

Because Red Mill Spring is lower in elevation than most of Hudson Brook and its tributaries to the east and southeast, these surface-water bodies could be a source of spring discharge. The concentrations of some inorganic constituents (table 3) determined by analysis of water samples of Hudson Brook (fig. 6) and Red Mill Spring taken during this investigation, however, indicate that the brook is not a source of spring discharge. Sodium and chloride concentrations in spring water (2.8 and 1.4 mg/L, respectively) were much lower than in stream water (28.1 and 63.0 mg/L, respectively).

Two maps (Herz, 1961; Ratcliffe and others, 1993) show the bedrock geology in the vicinity of the spring. The most recent map is based on the previous mapping and more recent field investigations and presents a geologic interpretation that is consistent with the prevailing regional geologic model for the western part of Massachusetts. The spring is shown (Ratcliffe and others, 1993) to be underlain by a calcite marble and very near to the marbles contact with dolostone, both units of the Stockbridge Formation. However, no bedrock is visible in the vicinity of the spring; the nearest known outcrop consists of schist of the Walloomsac Formation and is 0.37 mi to the southeast along Canyon Brook. The spring is on or very near the axis of an anticline that strikes generally north-south. Anticlines typically have sets of axial fractures, which are steeply dipping and parallel to the strike of the anticline. One or a series of these fractures may be the conduit that provides water to this spring. Bedrock at the spring is probably at shallow depth and is overlain by a thin deposit of till (Holmes, 1968).

The 0.322-mi^2 area contributing recharge shown on figure 6 is based on the interpreted geologic characteristics of the site and the rate of spring discharge. Ground water was assumed to flow to the spring from the south through fractures. If the spring consists of ground-water flow through solution fractures in the Stockbridge Formation, then the area contributing recharge could be north or northwest of the spring. The MADEP Zone 1 800-ft square is also shown on figure 6. The ground-water-recharge rate required to sustain the average discharge of 185 gal/min is 16.4 in/yr.

Fanny Rogers Spring

Fanny Rogers Spring in Cummington, MA, is located in an upland draw about 0.31 mi northeast of the intersection of Dodwell Hill and Lyman Flat Road (figs. 1, and 10, at back of report, table 1). This spring results from seepage, contact, and fracture flow at the base of the west slope of the draw.

Spring improvements include three closely spaced concrete collection basins with stainless steel covers (figs. 11*A* and 11*B*, at back of report). On average, the basins are about 9 ft long, 6 ft wide, and 4.5 ft deep. Each basin is drained by a 0.5-in.-diameter flexible plastic pipe to a central collection cistern 3 ft in diameter and 6.7 ft deep (fig. 11*A*). The cistern drains through a 2 in.-diameter flexible plastic pipe to an 80,000-gal storage tank downslope and adjacent to Dodwells Road. Spring discharge could be measured at this tank by using bypass valves that allow the spring discharge to flow to waste. It would have to flow for several days to drain water stored in the spring structures and collection cistern, however, and to stabilize the flow. A single discharge measurement of 2 gal/min was taken after the collection cistern was allowed to drain for 2 hours and the discharge had been adjusted to stabilize the water level in the cistern (table 2).

Fine-grained schist of the Goshen Formation underlies the site. The bedrock structure generally trends slightly east of north and is characterized by anticlinal and synclinal folds, some of which are overturned (Hatch, 1969). A nearly vertical bedrock fracture observed in one of the spring-collection structures strikes N. 20° W. and appears to be discharging water (fig. 11*C*). A thin layer of till overlies the bedrock.

The area contributing recharge has been extended to the northwest to reflect the influence of the observed fracture orientation. The area contributing recharge to the spring is estimated to be 0.17 mi^2 and the MADEP Zone 1 is a 518-ft square (fig. 10).

Keats Spring

Keats Spring is in a small swale just east of the ridge of the Pocumtuck Range and about 250 ft south of Pine Nook Road (figs. 1 and 12, at back of report, table 1). Improvements to the spring include an elliptical collection cistern that is 6 to 8 ft in diameter, 10.2 ft deep, and is stone-lined with an open bottom. The cistern is covered by a cement slab with a steel hatch for access (fig. 13, at back of report). Spring water discharges through a 4-in.-diameter steel pipe that is about 0.9 ft from the bottom of the cistern and flows by gravity downslope to Wells Spring where it is chlorinated and metered. A 4-in.-diameter overflow pipe near the top of the cistern discharges spring water on rare occasions. There was no information available on the maximum or average yield from the spring, but in most years, there is zero flow from late spring through early fall (Joseph Kostivk, Operator, Deerfield Fire District, oral commun., 2002).

The cistern was constructed in an area where water seeps from unconsolidated deposits that are composed of till and weathered red arkose, the sedimentary bedrock that underlies the site. The unconsolidated deposits are at least 11 ft thick at the spring site but thin to the west and southwest where bedrock outcrops are present near the crest of the Pocumtuck Range.

The area contributing recharge to the spring is estimated to be 0.063 mi^2 and the MADEP Zone 1 is a 344-ft square (fig. 12, table 4). The estimated area contributing recharge generally coincides with the surface-water divides of the small intermittent stream basin in which the spring is located.

Wells Spring

Wells Spring in Deerfield, MA is in a small swale just west of the ridge of the Pocumtuck Range and 150 ft north of Pine Nook Road (figs. 1 and 12, table 1). Improvements at the spring include a 5-ft-deep masonry collection basin constructed against a bedrock outcrop. The basin is covered by a small wood-frame spring house (fig. 14, at back of report). Historically, water discharging from a fracture in the bedrock was collected in the basin. At present, the spring discharges through a pipe sealed into the fracture. Water from this spring and Keats Spring is chlorinated and metered in the spring house and the combined discharge then flows by gravity downhill to the Deerfield Fire District's main storage reservoir. The discharge is reported to range from zero to about 15 gal/min and, in most years, there is no flow from late spring through early fall (Joseph Kostivk, Deerfield Fire District, oral commun., 2002).

The site is underlain by the Sugarloaf Formation, which is composed of a layered red arkose that dips about 30 degrees to the east (Willard, 1952). The spring discharges from a layer parallel fracture in the rock. Layer parallel fractures that are typical of this formation can conduct water parallel to the bedding. High-angle fractures that cut across the bedding are also typical of this formation in many locations. These high-angle fractures can serve as a source of ground-water recharge from the bedrock surface and can transmit water between layers. A thin layer of till covers the bedrock at the spring site (Jahns, 1966).

The area contributing recharge to the spring is estimated to be 0.078 mi^2 and the MADEP Zone 1 is a 344-ft square (fig. 12, table 4). The estimated area contributing recharge is extended in directions perpendicular to the bedrock slope to incorporate the presumed transmissivity of layer parallel fractures.

Harris and Stillwater Springs

Harris and Stillwater Springs in Deerfield, MA (figs. 1 and 15, at back of report, table 1), are within about 0.5 mi of each other in areas that are geologically similar. Stillwater Spring is about 600 ft southwest of the Stillwater Bridge at the base of a steep scarp. Harris Spring is 2700 ft south of Stillwater Spring at the base of the same scarp.

Improvements at the springs are similar and consist of a series of stone-lined collection boxes along the base of the scarp in areas where ground water is seeping. At Stillwater Spring, there are eight collection structures presently in use (fig. 16*A*, at back of report) and an additional nine that are not used at present. At Harris Spring, there are five collection structures (fig. 16*B*). Collected water flows by gravity in tile or plastic pipes to a cement collection cistern at each site. The cisterns at both springs drain to a single reservoir on Stillwater Road (fig. 16*C*) from which the water is pumped into the Deerfield Fire District water-distribution system.

It was not possible to measure the discharge from each spring, but the combined discharge was measured at the overflow of the combined reservoir when the pump was not running (fig. 16*D*). Measurements of the combined flow ranged from 21.2 to about 84.5 gal/min (table 2).

At both springs, ground water seeps from unconsolidated glacial material near the base of a scarp created by the post-glacial downcutting of the Deerfield River through thick glacial deltaic and lake-bottom deposits (Jahns, 1966). The scarp at both sites shows evidence of slumps.

The areas contributing recharge to Harris and Stillwater Springs are estimated to be 0.115 and 0.050 mi^2 and the MADEP Zone 1s are 950- and 805-ft squares (fig. 15). Based on combined average discharge and areas contributing recharge for both springs, an estimated 8.4 in/yr of ground-water recharge would be required to maintain the average combined discharge for both springs (table 4). This recharge value is an underestimate, however, because a large volume of spring seepage and ground-water underflow is not collected or accounted for in the calculation of recharge. At the request of MADEP, the sizes of the Zone 1 squares for these two sets of springs were increased by the distance between the end-collection structures (width of the collection area) at each spring site in order to keep the side offsets the same as those for point-source springs.

Guilder Hills Spring

Guilder Hills Spring in Egremont, MA, is in a small gully on the lower northeast slope of Mount Sterling and 0.48 mi south of the intersection of Jug End and Guilder Hills Roads (figs. 1 and 17, at back of report, table 1). Discharge measurements during the study ranged from 13.6 to 15.0 gal/min (table 2). Spring improvements include the large (17 ft by 13 ft by 1 ft) concrete collection-and-reservoir structure shown in figure 18, at back of report. The reservoir reportedly rests on bedrock 8 ft below ground surface (William Olmsted, Spring Operator, Guilder Hills Water System, oral commun. 2001). Discharge is pumped from the reservoir into a distribution system that supplies seven seasonal homes.

Calcite marble, one unit of the Stockbridge Formation, underlies the spring site (Zen and Ratcliffe, 1971). A thrust fault about 260 ft southwest of the spring separates the older phyllite of the Everett Formation, which caps the mountains to the southwest, from the younger Stockbridge Formation that underlies the valley area near the spring (Zen and Ratcliffe, 1971). It is unknown whether this fault or fractures in the marble are related to this spring. However, many springs in western Massachusetts are located in similar settings near thrust faults.

The area contributing recharge to the spring is estimated to be 0.054 mi^2 and the MADEP Zone 1 is a 600-ft square (fig. 17). An estimated 7.9 in/yr of ground-water recharge is required to maintain the average spring flow (table 4).

Whitcomb Summit Spring

Whitcomb Summit Spring in Florida, MA, is just west of Cascade Brook and about 0.23 mi upstream from Monroe Road (figs. 1 and 19, at back of report, table 1). Spring discharges measured during the study ranged from 12.5 to 14.0 gal/min (table 2). Spring improvements include a concrete collection structure that has dimensions 6 ft by 7 ft by 2.5 ft and rests on bedrock. A low A-frame wood enclosure covers the collection structure (fig. 20*A*, at back of report). Discharge drains through a 2-in.-diameter flexible plastic pipe into two large steel tanks (fig. 20*B*) about 225 ft downslope from the spring. From the tank, the water is pumped 0.45 mi uphill to the Whitcomb Summit Motel adjacent to Route 2.

The Rowe Schist, composed of either a very fine-grained quartzite or black schist, underlies the site (Herz, 1961). Thin till overlies the bedrock. Spring discharge may be a combination of seepage through the unconsolidated till and from fractures in the bedrock. The generally impermeable bedrock is at a very shallow depth at the spring location; ground water may be flowing onto the land surface at the contact between the schist and till.

The area contributing recharge to the spring is estimated to be 0.032 mi^2 and the MADEP Zone 1 is a 590-ft square (fig. 19). An estimated 12.7 in/yr of ground-water recharge is required to maintain average spring flow (table 4).

Granville Center Spring

Granville Center Spring in Granville, MA, is in a small upland swale 400 ft west of Blandford Road at a point 0.6 mi north of Granville center (figs. 1 and 21, at back of report, table 1). Spring improvements include a fieldstone-lined, partially mortared collection basin that is about 10.7 by 7.7 by 3.7 ft deep. The 5-in.-thick cement cover has a 2-ft-square hatch with a wood cover in the southwest corner (fig. 22, at back of report). A discharge pipe near the bottom of the basin is presently blocked and the spring is unused. When used, the spring flowed into a 50,000-gal buried storage tank just south of the spring. At present, water seeps out of the unmortared south face of the basin and flows around the storage tank and downhill to waste. This spring is maintained as a public-supply spring for possible use as an emergency water source.

Schist of the Cobble Mountain Formation (Knapp, 1978) underlies the spring site. The general north-south strike and moderate west-dipping bedrock structure reflects the site’s geologic setting on the west flank of the Granville Dome. Generally thin deposits of till overlie bedrock. The spring appears to result from seepage from the unconsolidated till.

The area contributing recharge to the spring is estimated to be 0.012 mi^2 and the MADEP Zone 1 is a 340-ft square (fig. 21). The 2.0 gal/min value used to determine the size of the Zone 1 square is an estimated discharge from the MADEP water-supply database.

Mount Blue Spring

Mount Blue Spring is in Wompatuck State Park in Hingham, MA. This is the only public-supply spring in eastern Massachusetts (figs. 1 and 23, at back of report, table 1). The site is at the base of a small hill 200 ft southwest of Union Street and 0.32 mi southeast of the entrance to the State Park campground (fig. 23). Discharge measurements made during the study ranged from 2.5 to 5.0 gal/min (table 2). Spring improvements include a 7-by-8-by-4-ft mortared-stone cistern that is covered by an A-frame building with a stainless-steel hatch (fig. 24, at back of report). On demand, spring discharge is pumped from the collection cistern through an ultraviolet-light (UV) disinfection unit to taps in a small adjacent building where transient users fill water containers. An overflow pipe in the collection structure maintains a constant water level in the cistern. Unused spring water discharges to waste about 50 ft east of the spring.

The depth to the Dedham Granite that underlies the site (Zen, 1983) is unknown and no outcrops are nearby. Saturated sand and gravel of unknown thickness is overlain at land surface by 2 to 3 ft of low-permeability, dense gray, boulder till. The piezometric head in the sand and gravel is slightly above the land surface. These artesian conditions cause the water level in the spring cistern to rise slightly above the land surface and account for the numerous ground-water seeps adjacent to the spring and along the base of the hill.

The area contributing recharge to the spring is estimated to be 0.020 mi^2 and the MADEP Zone 1 is a 457-ft square (fig. 24). An estimated 5.8 in. of ground-water recharge is required to maintain average spring flow (table 4).

Berkshire Spring

Berkshire Spring in Lanesborough, MA, is just south of Summer Street about 350 ft west of its intersection with State Road (figs. 1 and 25, at back of report, table 1). The spring is enclosed by a cement vault (fig. 26*A*, at back of report) whose dimensions are approximately 10.8 by 11.7 by 9.7 ft; 2.6 ft of the 9.7-ft height is below land surface. The enclosed reservoir has a storage capacity of about 2,081 gal. Four pipes draw water from the reservoir: one supplies the Berkshire Cooperative pump house on the north bank of the Hoosic River about 250 ft east of the spring, a second feeds a public watering trough just west of the spring that serves a large number of transient users (fig. 26*B*), a third feeds two or three private homes on the shore of Cheshire Reservoir, and a fourth tile pipe just above land surface serves as an overflow to drain excess spring flow. The drain outlet could not be located and presumably discharges into Cheshire Reservoir north of the spring. The estimated discharge is 50 to 60 gal/min. This value is based on measurements of some of the flow components and estimates of others.

The Clarendon Springs dolomite, a calcite dolomite, underlies the spring site (Herz, 1958). The tight anticlinal bedrock structure at the site trends slightly east of north (Herz, 1958 and Ratcliffe, 1984). Axial north-south trending and steeply dipping fractures were observed on a bedrock outcrop just to the east of the spring (fig. 26*C*). About 300 ft east of the spring a north-south and eastward dipping thrust fault separates the Clarendon Springs dolomite from other bedrock units (Herz, 1958). The mapped fault contact generally follows the west side of Berkshire Pond (fig. 25).

The spring is lower in elevation than Berkshire Pond to the east (fig. 25). Analysis of water samples taken during this investigation to determine physical properties and the concentrations of some inorganic constituents (table 3), semi-annual water-quality results from samples required by MADEP, and records kept by the spring operator indicate that the pond is not the source of spring discharge. Sodium and chloride concentrations in spring water are consistently low and water temperature is constant at 48°F (William DiLego, Operator, Berkshire Cooperative, oral commun., 2001). Sodium and chloride concentrations of water in Berkshire Pond, an impoundment on the Hoosic River, are seasonally at least 10 times higher than in spring water (table 3) and temperature is seasonally variable. The combined chemical and temperature data indicate that Berkshire Pond is not the source of spring discharge.

The area contributing recharge to the spring is estimated to be 0.152 mi^2 (fig. 25) and is based on a hydrologic interpretation of the geologic setting. Ground water may flow to the spring from the south along the north-south trending axial-plane fractures. Alternatively, the thrust fault east of the spring may provide a conduit for water to the spring. If so, the spring recharge area may be east of the Hoosic River valley in the area of North Mountain as suggested in a previous report describing the water resources of area (Motts, 1990). An estimated 12.0 in/yr of ground-water recharge within the area contributing recharge is required to sustain average spring flow (table 4). The 800-ft-square MADEP Zone 1 is shown on figure 25.

Cold Spring

Cold Spring in Lee, MA, is sited near the base of a steep hill and is about 100 ft east of Tyringham Road 0.74 road mile south of its intersection with Route 102 (figs. 1 and 27, at back of report, table 1). Ground water seeps from an area that is just upslope from the base of the hill. The seepage area extends about 50 ft in a direction parallel to the slope and is about 25 ft wide. Adjacent areas at the same elevation are dry. Spring improvements include two open-bottom, 2-ft-diameter, stainless-steel collection tanks that are buried in the seepage area and are backfilled with crushed stone. A flexible plastic discharge pipe which is 0.5 in. in diameter drains discharge from the tanks to a watering trough about 40 ft downslope at the edge of Tyringham Road (fig. 28, at back of report). Many transient users fill containers with spring water at the watering trough for later use at home or elsewhere. The stainless-steel tanks collect only part of the spring discharge; the excess seepage flows downgradient into a ditch parallel to Tyringham Road and then to a culvert under the road that drains all of the spring discharge. During the study, measurements were made of discharge at the watering trough and the total discharge from the seepage area where it flows through the culvert under

Tyringham Road. The total discharge through the culvert ranged from 7.1 to 28.1 gal/min (table 2). The physical properties and concentrations of major inorganic constituents and nutrients of a spring-water sample are listed in table 3.

The spring is sited on or near a thrust fault that separates the overlying older metaquartzite of the Dalton Formation from a younger dolomite marble unit of the Stockbridge Formation (Ratcliffe, 1985). The bedrock geologic map of the area indicates that the older metaquartzite of the Dalton Formation overlies the younger dolomite marble of the Stockbridge Formation at the site and the mapped location of the thrust fault is just to the west of the spring (Ratcliffe, 1985). There are no bedrock outcrops in the immediate area, however; only thin till overlies bedrock. Information available for this site indicates that spring flow originates from either a fracture or solution channel in the bedrock.

The area contributing recharge to the spring is estimated to be 0.047 mi^2 and the MADEP Zone 1 is a 682-ft square (fig. 27). An estimated 9.1 in/yr of ground-water recharge is required to maintain average spring flow (table 4).

Mill River Road Springs 1 and 2

Mill River Road Springs 1 and 2 are 75 ft east of and just east of Mill River Road respectively, and are 0.3 to 0.4 mi south of Mill River Village in New Marlborough, MA (figs. 1 and 29, at back of report, table 1). Spring 1 is enclosed by an open-bottom vertical cement pipe 3 ft in diameter with a cement cover (fig. 30*A*, at back of report). Discharge from Spring 1 flows by gravity through a pipe to Spring 2. At Spring 2, a wooden A-frame spring house (fig. 30*B*) covers an open-bottom cement collection basin and reservoir that has dimensions 23.3 by 18.2 by 3.0 ft, and has a capacity of 6,550 gal (fig. 30*C*). An overflow pipe maintains a water depth of about 2.3 ft inside the reservoir. Water in the reservoir is disinfected by periodic injections of chlorine directly into the reservoir. The chlorinator is located in a small building attached to the south end of the spring house (fig. 30*B*). Water from the Spring 2 reservoir is piped by gravity downgradient to Mill River Village, where it is distributed to customers of the Mill River Water Takers Association. Two measurements of overflow discharge through a culvert under Mill River Road averaged 2.6 gal/min (table 2), but the measurements did not include usage and are, therefore, a poor estimate of total discharge.

A dolomitic marble unit of the Stockbridge Formation (Ratcliffe and Burger, 1975) is overlain by ice-contact sand and gravel. A linearly extensive ice-contact sand and gravel deposit extends from the Mill River west of the springs to about the 950-ft (290-m) elevation contour along the east side of the valley (Holmes and Newman, 1971; and Warren, 1978). Above this elevation, the upper slope of Leffingwell Hill has many bedrock outcrops and a thin cover of till. Surface topography and the configuration of the sand and gravel deposit indicate that the sand and gravel is thin between the spring and the Mill River to the west. East of the springs, the sand and gravel may be as thick as 200 ft in places, but thins near the contact with till on the east edge of the deposit. A clay deposit adjacent to the west and north sides of Spring 1 may have been deposited in a glacial lake, but more likely, was deposited by local residents in the 1700s or 1800s to dam natural seepage in order to enhance the collection of spring water. Ground-water recharge to the sand and gravel deposits east of the spring (about 20 to 25 in/yr) is probably increased by infiltration of surface-water runoff from the steep upper slopes onto the highly permeable sand and gravel deposits. Therefore, the estimated area contributing recharge extends east from the spring up onto Leffingwell Hill. The area contributing recharge to the spring is estimated to be 0.086 mi^2 and the MADEP Zone 1 is a 376-ft square (fig. 29, table 4).

Peru Roadside Spring

Peru Roadside Spring in Peru, MA is adjacent to the south side of Route 43 1.2 mi east of the center of Peru, and is sited on a gentle northeast-sloping hillside (figs. 1 and 31, at back of report, table 1). Discharge measurements made during this study ranged from 0.9 to 1.28 gal/min (table 2). Improvements at the spring consist of a 6.7-ft-square cement vault with a 1.5-in. pipe from which water discharges (fig. 32, at back of report). Many local residents use this roadside spring as a source of drinking water.

No bedrock outcrops are present in the immediate area of the spring, but the till covering the medium to coarse-grained schist of the underlying Hoosic Formation (Norton, 1974b) is probably thin. This contact or seepage spring appears to issue from unconsolidated deposits. Because bedrock is close to the surface, however, fracture flow may contribute to spring discharge.

The area contributing recharge to the spring is estimated to be 0.013 mi^2 and the MADEP Zone 1 is a 280-ft square (fig. 31). An estimated 2.4 in/yr of ground-water recharge is required to maintain the average spring flow observed during the study (table 4).

Farm House, Red Rock, Barrel, and Smith Springs

Farm House, Red Rock, Barrel and Smith Springs in Sheffield, MA, are in the northeastern section of Sheffield in an area north and south of Water Farm Road about 0.5 mi south of its intersection with Holmes Road (figs. 1 and 33, at back of report, table 1). The springs are a source of water to the Sheffield Water Company.

Spring improvements are different for each spring. Farm House Spring is south of Water Farm Road in a seepage area at the base of a steep slope (fig. 33). This spring has a 6-ft-square, 5.7-ft-deep cement collection cistern (fig. 34*A*), the bottom of which is 3.9 ft below land surface. This spring drains to a reservoir in a vault (fig. 34*E*) near Water Farm Road where it is pumped into the water-company distribution system.

Red Rock Spring is south of Water Farm Road on the south face of a bedrock knob (fig. 33) at the highest topographic location in the spring-water-collection system. This spring is inside a horizontal gallery 4 ft wide, 5 ft high, and 3 ft deep that has been excavated into fractured red bedrock. A cement face and small wooden door enclose the gallery (fig. 34*B* and *C*, at back of report). The spring is drained by gravity to Barrel Spring through a 2-in.-diameter flexible plastic pipe.

Barrel Spring is south of Water Farm Road in a seepage area in the bottom of a gully (fig. 33). The collection structure for this spring is a vertical cement pipe 30 in. in diameter and 4 ft long with an open bottom and cement cover (fig. 34D). Red Rock Spring drains into this structure and the combined discharge from both springs drains by gravity through a 2-in. flexible plastic pipe to a large storage reservoir near Water Farm Road (fig. 34*E*). This storage reservoir feeds by gravity into the water-company distribution system. Excess discharge overflows into Soda Creek. The maximum water level in this reservoir is reported to be equal or almost equal to the maximum water level in Smith Spring to which it is connected.

Smith Spring is west of Water Farm Road at the base of a steep slope (fig. 33) and has a 39-by-20.3-by-3-ft cement collection basin that is covered by a wooden spring house (fig. 34*F*). This spring feeds by gravity into the water-company distribution system and drains its excess water to Soda Creek (fig. 34*G* and *H*). It was reported that this spring flows at 200 gal/min from quartzite bedrock (Norvitch and Lamb, 1966). Presently, however, there is no bedrock visible at the site.

Units of the Dalton Formation (Ratcliffe, 1975) underlie the upslope area beneath Red Rock, Barrel and Farm House Springs. These units include metaquartzites and schist. Smith Spring is on, or close to, a thrust fault that separates an underlying white calcite marble unit of the Stockbridge Formation from an overlying schist unit of the Dalton Formation (Ratcliffe, 1975). The spring may be discharging from fractured bedrock around the fault. Thin surficial deposits of till overlie bedrock across the entire area.

The combined area contributing recharge to the four springs is estimated to be 0.056 mi^2 and the dimensions of the MADEP Zone 1 squares for each spring are 468, 376, 376, and 468 ft, respectively (fig. 33, table 4). The estimated spring discharge rates used to calculate the Zone 1 protection areas are from MADEP water-supply records (table 4).

Goulds Sugarhouse Spring

Goulds Sugarhouse Spring in Shelburne, MA, is about 925 ft west of Tower Road and 600 ft north of Route 2 (figs. 1, table 1). It is sited just west of a small stream that flows off the south slope of Massaemett Mountain. Spring improvements include a 4-ft diameter, 8-ft-long, vertical cement pipe with an open bottom and metal cover (fig. 36, at back of report). A buried 0.5-in. flexible plastic pipe 7.7 ft below the top of the cement pipe drains spring discharge about 550 ft downhill to a 500-gal cement storage tank. This tank is located in the basement of Gould's Sugarhouse Restaurant adjacent to Route 2. Water from the tank is pumped to supply the restaurant and sugarhouse operations. A spring discharge of 1.2 gal/min was measured in June 2001 (table 2).

Bedded schist, quartzite, and rarely occurring marble of the Conway Formation underlie the site (Segerstrom, 1956). Bedrock is probably at shallow depth, but the closest exposure is located about 500 ft upslope from the spring. The surficial deposits at and adjacent to the spring are poorly graded sand and gravel deposited in an esker on a hillside high above the valley bottom (Segerstrom, 1959). The spring is in a seepage or contact area where the more permeable sand and gravel thins above the contact with less permeable till or underlying bedrock. Bedrock is probably at shallow depth at the spring, but no outcrops were observed.

The area contributing recharge to the spring is estimated to be 0.013 mi^2 and the MADEP Zone 1 is a 272-ft square (fig. 35, at back of report). An estimated 2.9 in/yr of groundwater recharge is required to maintain average spring flow (table 4).

High Lawn Farm Spring

High Lawn Farm Spring in Stockbridge, MA, is at the base of Rattlesnake Hill about 0.81 mi northwest of the intersection of Route 7 and West Road (fig. 1, table1). Spring improvements include a mortared-stone spring house (fig. 38*A*, at back of report) that is 24 ft long, 10.2 ft wide, and 8.2 ft deep. The spring house is built against a bedrock outcrop. The spring flows from a solution-enlarged fracture (fig. 38*B*). From the spring house discharge flows by gravity to two 6,000-gal buried cement storage tanks at a pump house about 100 ft southeast of the spring (fig. 38*C*). Water is pumped to a 100,000-gal storage reservoir 3000 ft northwest of the pump house near the ridge line of Rattlesnake Hill. From this reservoir, water gravity feeds to a distribution system at High Lawn Farm on Summer Street in Lee, MA. The farm's dairy and approximately 14 households use the spring water. A spring discharge of 47 gal/min, was measured in August 2002 (table 2). A spring discharge ranging from 50 to 80 gal/min, had previously been reported (Peterson and Maevsky, 1962 and Norvitch and Lamb, 1966).

The geologic setting of this spring is complex. The spring is sited on a thrust fault that separates the older underlying calcite schistose marble of the Walloomsac Formation from a younger calcitic dolostone or dolomitic marble unit of the Stockbridge Formation (Ratcliffe, 1974) from which the spring flows. Sinkholes characteristic of karst topography were observed in the mapped outcrop area of the Stockbridge Formation to the west and north of the spring site. "Karst describes landscape characterized by caves, sinkholes, underground streams, and other features formed by the slow dissolving, rather than mechanical eroding, of bedrock" (Veni, and others, 2001). A second thrust fault about 900 ft west of the spring separates the Stockbridge Formation from the older and overlying metaquartzites of the Dalton Formation (Ratcliffe, 1974) that cap Rattlesnake Hill. The Stockbridge Formation underlies a large area of Rattlesnake Hill (Ratcliffe, 1974). Hydrogeologically, this geologic setting is interpreted as an extensive subsurface collection area that feeds water to High Lawn Farm Spring.

The area contributing recharge to the spring is estimated to be 0.682 mi^2 and the MADEP Zone 1 is an 800-ft square (fig. 37, at back of report). An estimated 2.9 in/yr of ground-water recharge (table 4) is required to maintain an estimated average spring flow of 65 gal/min/yr.

Waubeeka Springs

Waubeeka Springs in Williamstown, MA, is the largest public-supply spring in Massachusetts. The spring is near the base of the north flank of Brodie Mountain, 1.16 mi due south of South Williamstown, and 0.41 mi west of Route 7 (figs. 1 and 39, at back of report, table 1). This source is actually two springs about 190 ft apart.

Spring improvements include 4-ft-diameter, open-bottom, cement collection structures that extend 13.9 ft (west spring) and 8.4 ft (east spring) below land surface. These structures have cement covers with stainless-steel hatches (fig. 40*A*, at back of report). Plastic discharge pipes with 10-in. diameters near the bottoms of the structures conduct discharge about 425 ft downslope to two 10,000-gal buried cement storage tanks. Each spring structure has a 10-in.-diameter plastic overflow pipe that discharges excess water about 100 ft downslope from each spring. The downslope storage tanks have one 10-in.- and two 4-in.-diameter overflow pipes that drain excess discharge from both tanks (fig. 40*B*). Water flows by gravity from the storage tanks to the center of South Williamstown, where there are about 20 domestic and commercial connections (Alan Kapilloff, Waubeeka Springs Deeded Users, oral commun., 2001). Discharge measured during the study ranged from 49 to 240 gal/min; these measurements don't include water usage at the time of the measurement (table 2). Discharge is so large at times that all of the spring and reservoir overflow pipes are full and additional water overflows from beneath the reservoir covers (Alan Kapilloff, Waubeeka Springs Deeded Users, oral commun., 2001). This information indicates that the maximum discharge is larger than was measured during this investigation.

The geologic setting at this site appears to be similar to that of High Lawn Farm Spring site in Stockbridge, MA, that was described earlier in the report. This spring site is underlain by a calcitic rock unit of the Stockbridge Formation (Dale, 1923; Skehan, 2001; and Zen, 1983). The site is probably on or topographically and geologically just below a thrust fault that separates the younger and underlying Stockbridge rocks from older overlying schist of the Walloomsac Formation, which forms the crest of Brodie Mountain. The springs probably discharge from solution channels in a calcite rock unit of the Stockbridge Formation, which may underlie a large area of Brodie Mountain. This mechanism may also account for the large discharge.

The area contributing recharge to the spring is estimated to be 0.141 mi^2 (fig. 39). An estimated 24.4 in/yr of ground-water recharge is required to maintain the average discharge to this area. This large recharge rate indicates that the recharge area may be too small. A lack of definitive hydrogeologic information however, precludes the delineation of an expanded area. The MADEP Zone 1s are 800-ft squares (fig. 39).

Worthington Fire District Spring 1–4

Worthington Fire District (WFD) Springs 1 to 4 in Worthington, MA are east and west of Cold Ridge Road 0.3 to 0.5 mi north of its intersection with Buffington Hill Road (figs. 1 and 41, at back of report). Springs 1–3 are in seepage areas on the side of a gentle east-facing slope. Spring 4 is in a small draw on the same slope. The physical characteristics of the springs are listed in table 1.

Improvements at springs 1–3 are similar. Each spring has an open-bottom cement collection vault with a stainless-steel hatch (fig. 42, at back of report). The bottoms of the vaults are 5.2 to 6.1 ft below land surface and rest on the bedrock surface (John Sullivan, Worthington Fire District Operator, oral commun., 2001). The vault for Spring 1 is connected to a second vault that contains WFD Bedrock Well No. 2. A valved, 4-in.-diameter plastic pipe located about 1 ft above the bottom of the vault drains discharge from each spring. Each spring vault has a valved 4-in.-diameter cleanout drain on the bottom of the vault. The three springs drain to a large covered reservoir about 650 ft east of Cold Ridge Road. Spring 4, which is presently unused, is an open bottom cement vault 5.2 ft wide and 7 ft long. The bottom of the vault is only 1.6 ft below land surface. During an average year, the springs dry up by late June and start flowing again by late October (John Sullivan, Worthington Fire District Operator, oral commun., 2001). During the study, no discharges were measured because the plumbing made discharge inaccessible.

The bedrock underlying the site is carbonaceous schist and phyllite of the Goshen Formation in north-trending, steeply dipping, subparrallel bands (Hatch, 1969). No faults are mapped in the spring area. The area is covered by a 4-to-6-ft-thick layer of till. The surficial till deposits are only seasonally saturated. Periods of spring flow correspond to periods of ground-water recharge after heavy precipitation and periods when evapotranspiration is minimal and the water table rises above the bedrock surface. Flow from fractures in the bedrock may also contribute to spring flow.

The areas contributing recharge to Spring 1, Springs 2 and 3, and Spring 4 are estimated to be 0.010, 0.010, and 0.094 mi^2 (fig. 41), respectively, and the four MADEP Zone 1s are 292-ft squares (table 4).

Description of Detailed Studies

The hydrogeologic conditions in the immediate vicinities of two springs were investigated in order to delineate the water table in detail and the area contributing ground-water recharge to the source. This area was then compared to the MADEP Zone 1 Protection Area that is required for each public-supply spring. For this detailed investigation, areas were chosen where the water table was close to the land surface and small-diameter (1.25 in.) observation wells could be installed by hand auguring or driving.

Mount Blue Spring

Mount Blue Spring in Hingham, MA (figs. 1 and 23), was described in a previous section. The investigation at this spring included the installation of three hand-augured wells, collection and logging of lithologic samples from the three borings, measurement of water levels in four wells (one observation well was already present) and in the spring cistern, and an elevation survey of all surface and ground-water observation and measurement points.

Lithologic samples indicate that the shallow subsurface is characterized by a sand and gravel layer that is overlain by about 3 ft of dense low-permeability till that acts as a confining layer, as evidenced by the seeps and small springs east and west of the main spring where the confining layer has been locally breached. A water-table map for the immediate vicinity of Mount Blue Spring was constructed from the water-level data (fig. 43). Ground-water-flow lines were drawn on the water-table map and the zone contributing water to the spring was delineated and is shown on figure 43. The area contributing recharge based on the detailed water-table map fits well within the 457-ft-square MADEP Zone 1 Protective Area (fig. 23 and table 4) and is narrower (0.2 times the original width) than the area contributing recharge determined during the reconnaissance study. Additional water-level data from the area just south of the area contributing recharge delineated in the detailed investigation may have resulted in defining a slightly larger area contributing recharge.

Silver Brook Café Spring

The Silver Brook Café Spring in Sandisfield, MA, is located about 200 ft west of the intersection of Sandisfield Road and Route 57 in the community of West New Boston (figs. 1 and 44, at back of report). It is sited on the north edge of a low terrace that perennially seeps water. The water source for the Café, which is located in this area, consists of an open-bottom 3-ft-diameter covered cement pipe that serves as a collection structure (fig. 45, at back of report). The bottom of the pipe is 3.2 ft below land surface. Water is pumped from the site to the Silver Brook Café. The MADEP has recently classified this source as a well because the plumbing allows the water level to be drawn below a natural level in the collection structure and thus can induce additional discharge. Therefore, no Zone 1 and area contributing recharge are reported for this water source formerly classified as a spring.

The investigation at this site included the installation of nine hand-augured wells, collection and logging of lithologic samples, measurement of water levels in the nine wells (fig. 45*C*) and in the supply well, and an elevation survey of all surface- and ground-water observation and measurement points.

The shallow subsurface lithology is characterized by coarse sand and gravel that is overlain by 2.5 to 3 ft of clay. As at the Mill River Road Spring described previously, this clay may have been deposited in a local glacial lake, but more likely was deposited by local residents in the 1700s or 1800s to dam a natural seepage area and enhance the collection of spring water. A detailed water-table map of the immediate vicinity of Silver Brook Café Spring was constructed from the water-level and elevation data (fig. 46, at back of report). Ground-water-flow lines were drawn on the water-table map and a section of the area contributing recharge adjacent to the spring was delineated and is also shown on figure 46. This section of the area contributing recharge just upgradient of the spring is only about 20 ft wide.

Summary and Conclusions

Geohydrologic information to more accurately delineate the area contributing recharge to existing public-water-supply springs in Massachusetts is needed. The U.S. Geological Survey (USGS) in cooperation with the MADEP conducted an investigation of existing public-supply springs during the years 2001 to 2003 with two objectives. The first objective was to characterize each spring and the second was to delineate the area contributing recharge to each spring.

The characteristics of 28 public-supply springs, 27 of which are in Western Massachusetts, are described on the basis of reconnaissance investigations. Investigations of each spring included the collection of physical, hydraulic, and geologic data from published and unpublished records; and visits during which topographic, hydrogeologic, and historical information was collected, and during which the physical setting of the spring was observed and photographed, and where possible, spring discharge was measured. To determine seasonal variation, discharge from 12 springs was measured periodically from June 2001 to November 2002. The discharge of Red Mill Spring in Clarksburg, MA, was recorded continuously from April 2002 to November 2002. Discharge ranged from no recorded flow at several small intermittent springs to more than 240 gal/min at Waubeeka Springs in Williamstown, MA. The area contributing recharge for each spring was delineated on the basis of geohydrologic conditions at each site and ranged from 0.010 to 0.682 mi^2. Ground-water recharge, estimated on the basis of average annual discharge and the area contributing recharge, ranged from 0.5 to 24.4 in/yr. Low recharge rates may indicate recharge areas that are too large, but at many sites the low recharge rates results from much of the discharge being uncollected and unmeasured or from ground-water underflow. High ground-water recharge rates for several of the high-discharge springs indicate that the areas contributing recharge for these springs may be too small. Additional geohydrologic information would be required however, to support any adjustment to the size of the area contributing recharge at these sites. Detailed water-table mapping at two low-discharge springs indicates that the area contributing recharge to some of the smaller springs may be smaller than the area delineated by using the less precise information from the reconnaissance investigation.

Many of the springs, and especially the larger springs in the carbonate geologic terrane of western Massachusetts, are located on or in close proximity to major geologic features such as thrust faults and sinkholes. This proximity strongly suggests that the location and the high yields of some springs in this area are strongly affected by the bedrock structure or lithology.

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Figures 1–46

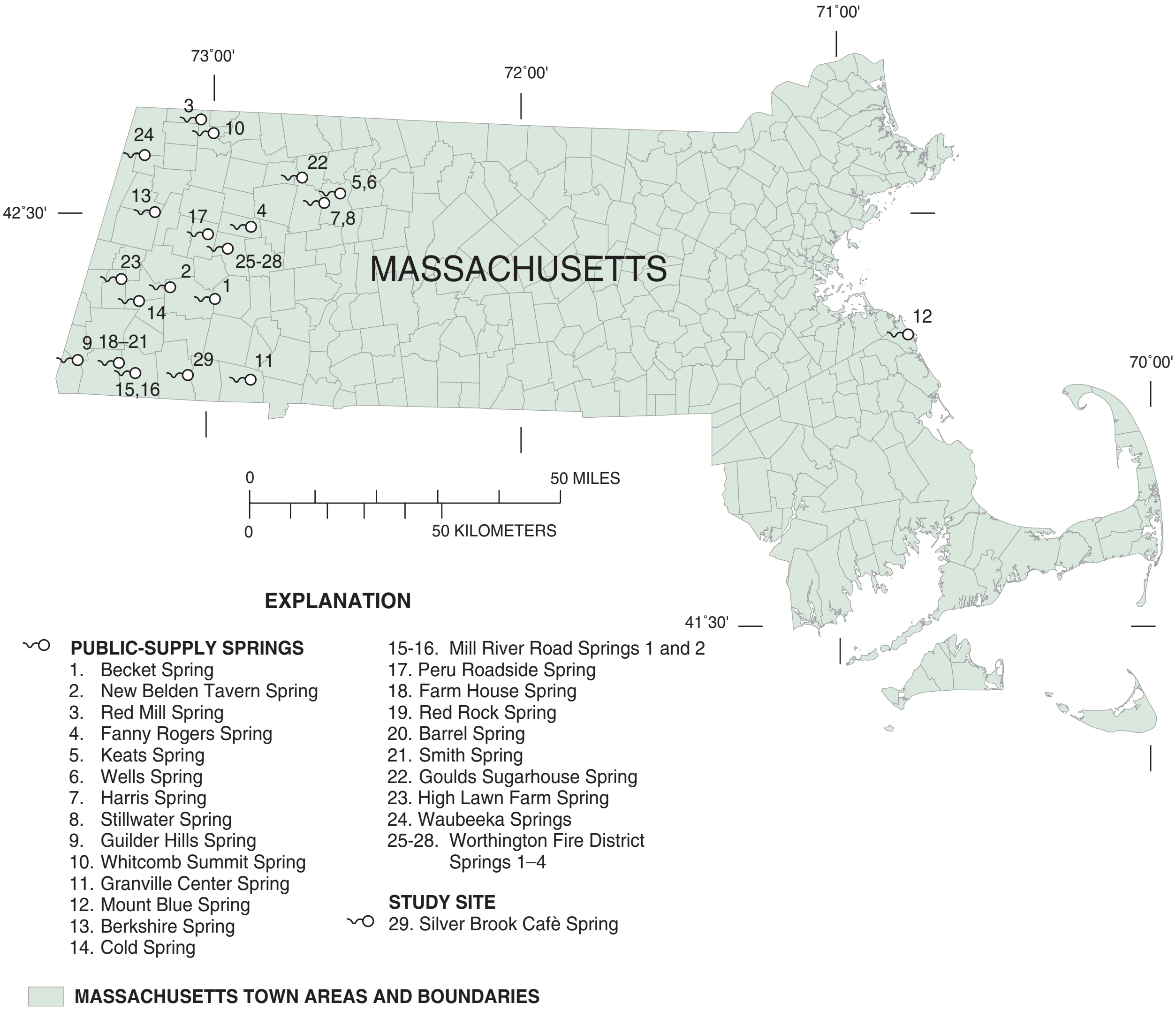
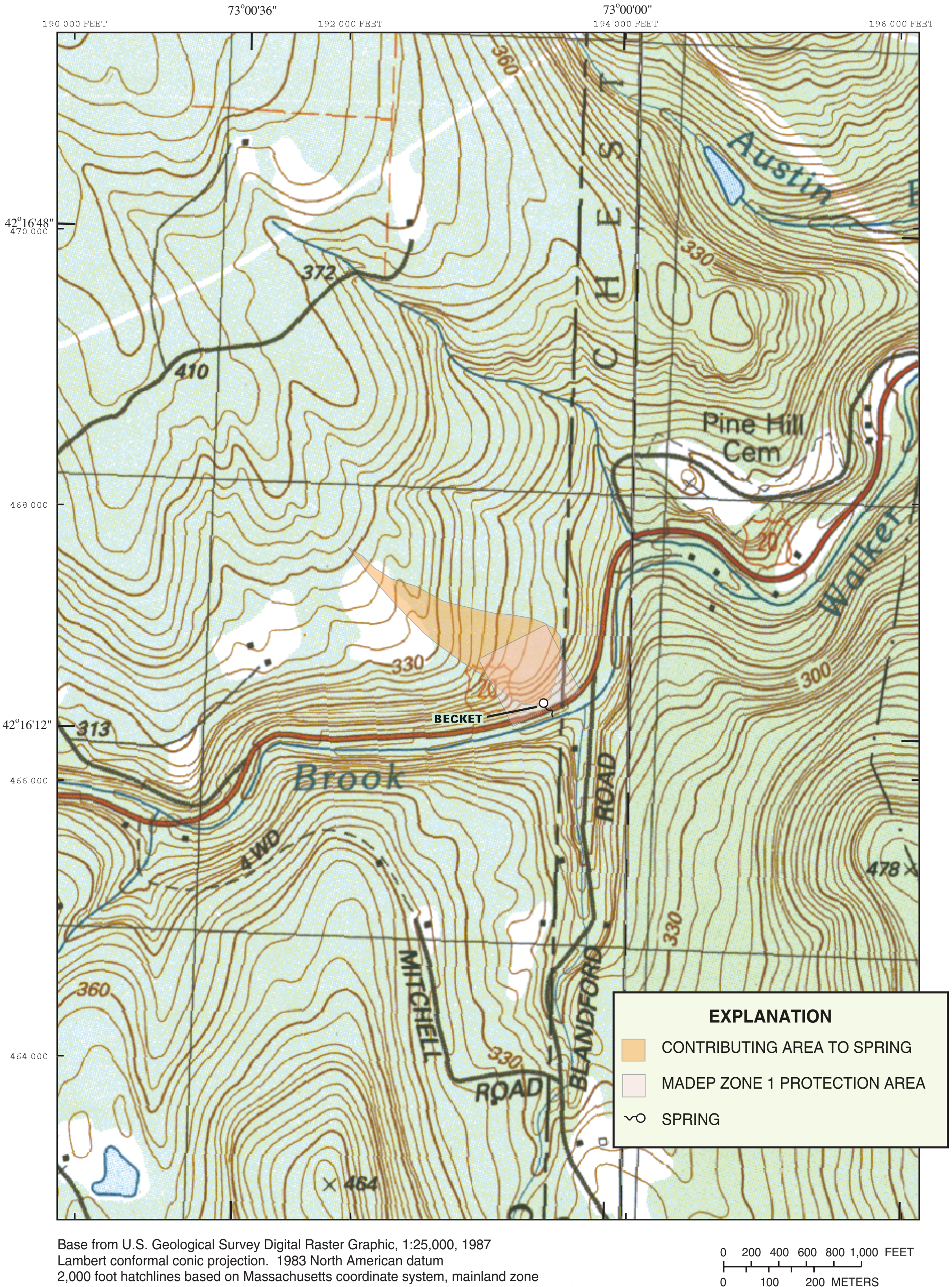


Figure 1. Public-supply springs and study sites in Massachusetts.



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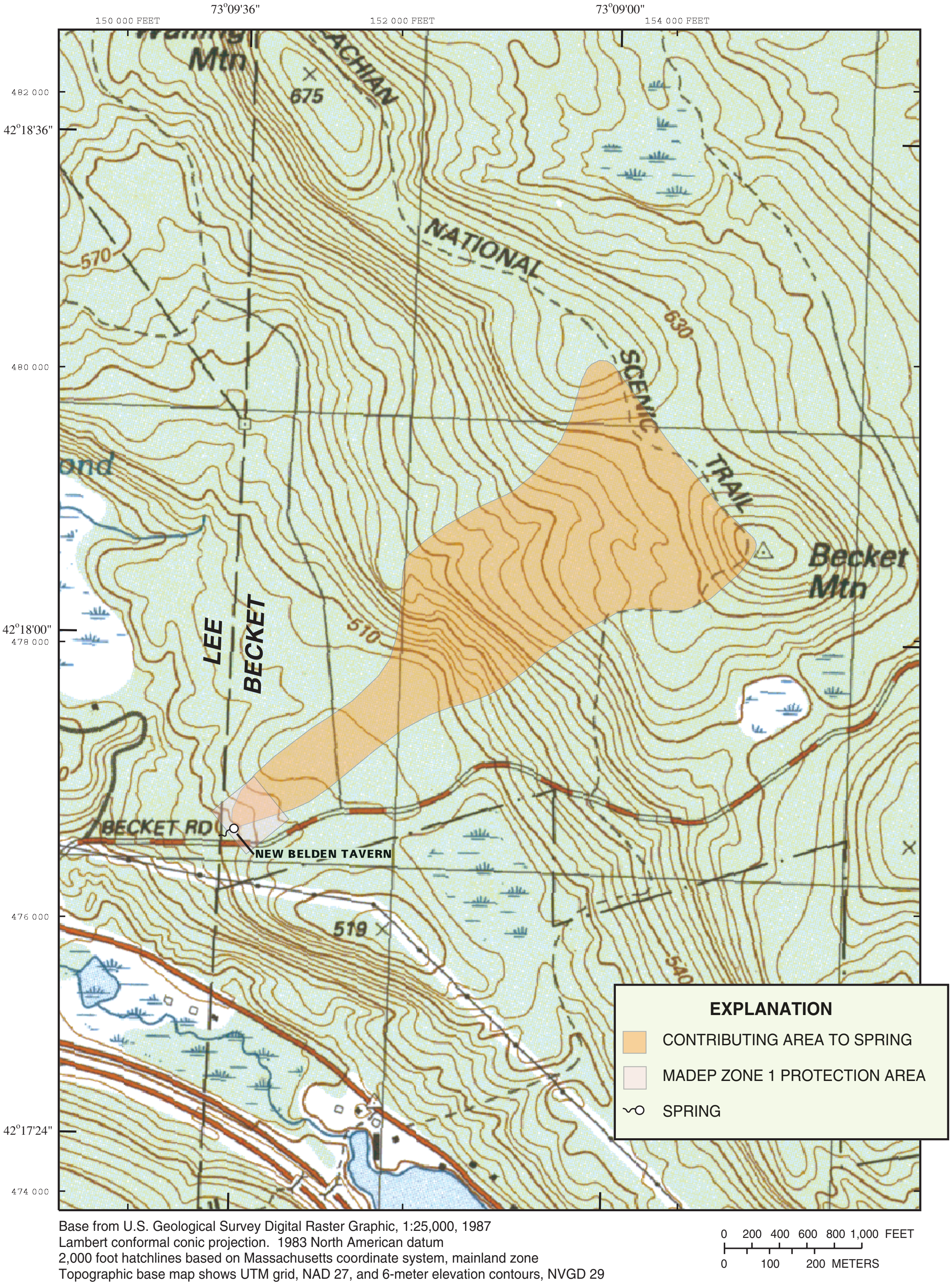
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 2. Becket Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Becket, Massachusetts.

Figure 3. Becket Spring with two discharge pipes, northwestward view, Becket, Massachusetts. Photograph by Joseph Cerutti, Massachusetts Department of Environmental Protection.



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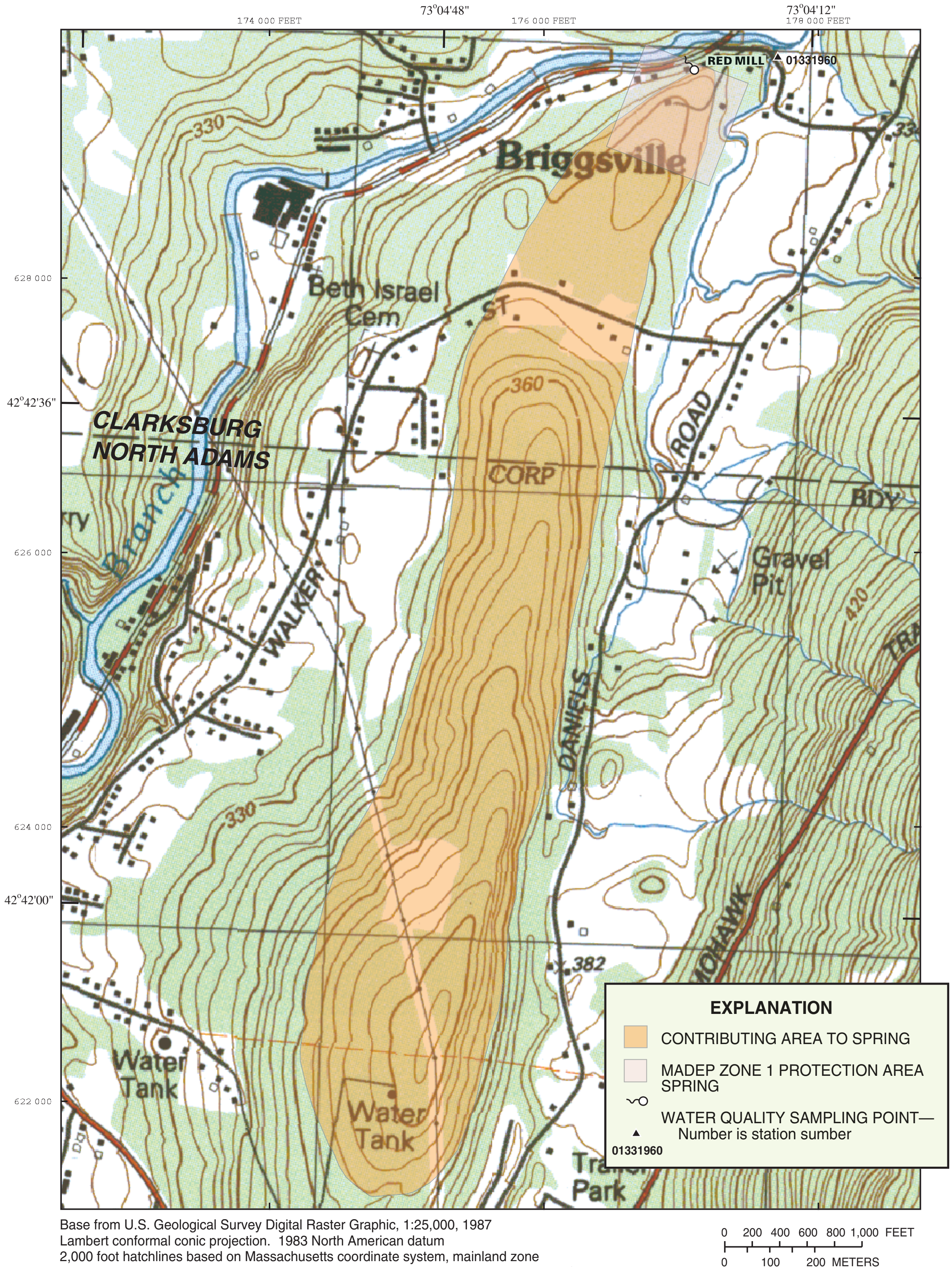
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 4. New Belden Tavern Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Becket, Massachusetts.

Figure 5. New Belden Tavern Spring in Becket, Massachusetts showing *A*, covered collection basin against boulder, northwestward view; and *B,* water flowing into collection basin from under boulder. Photographs by Joseph Cerutti, Massachusetts Department of Environmental Protection.



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Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 6. Red Mill Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Clarksburg, Massachusetts.

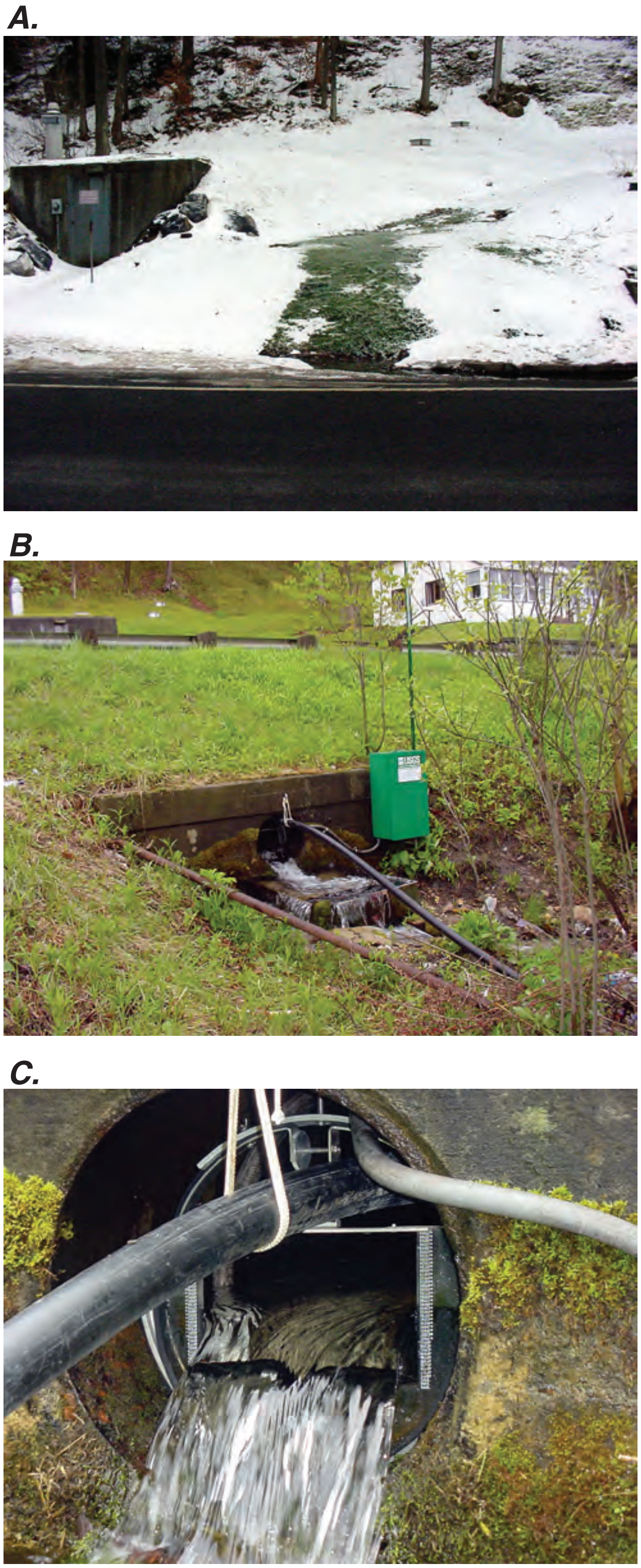


Figure 7. Red Mill Spring in Clarksburg, Massachusetts, showing *A*, two cisterns at upper center right, storage tank at left, and seepage melting snow at center, southeastward view; *B*, stage-discharge recording site on northwest side of Route 8, southeastward view; and *C*, close-up of weir installed in culvert with suspended 2-inch intake pipe for golf-course pump.

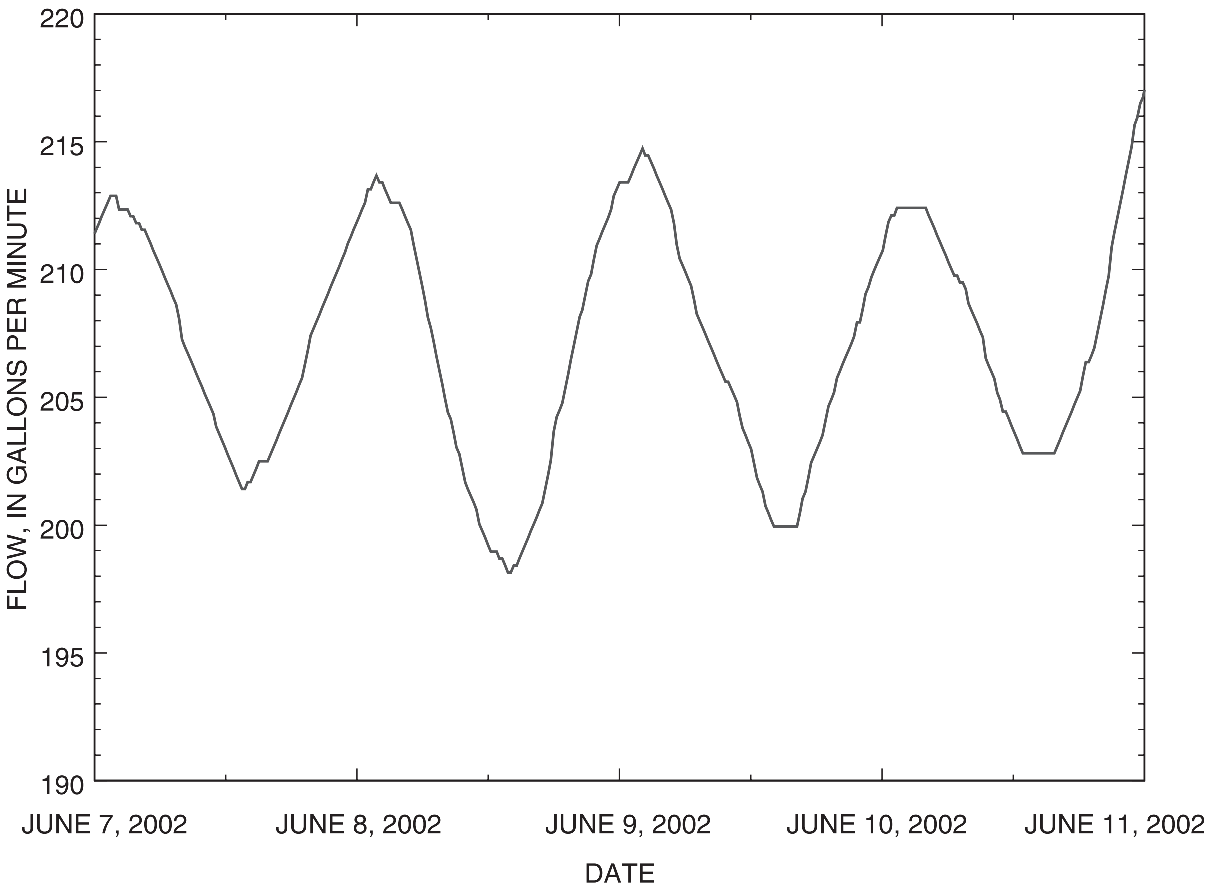


Figure 8. Record of continuous overflow discharge from Red Mill Spring, Clarksburg, Massachusetts, June 7–11, 2002.

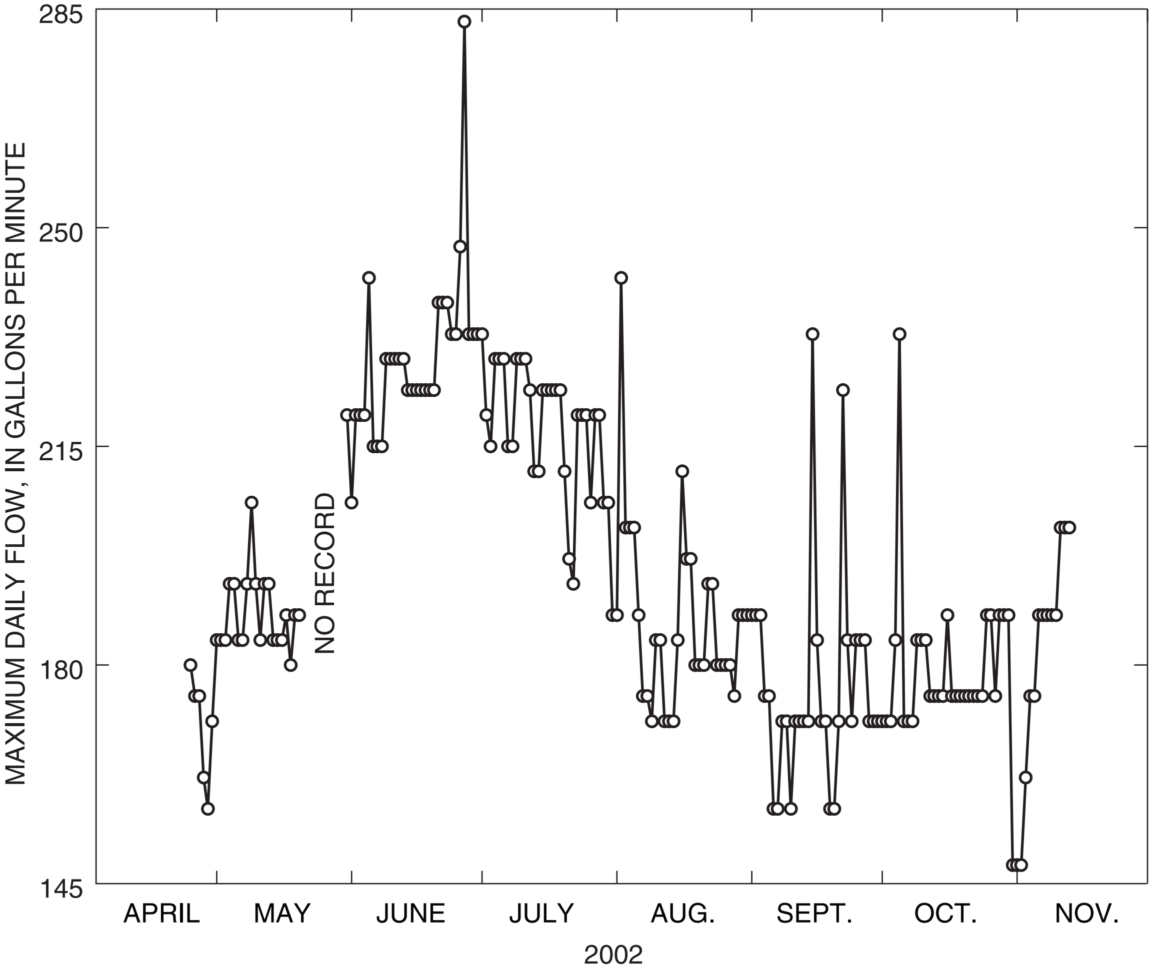
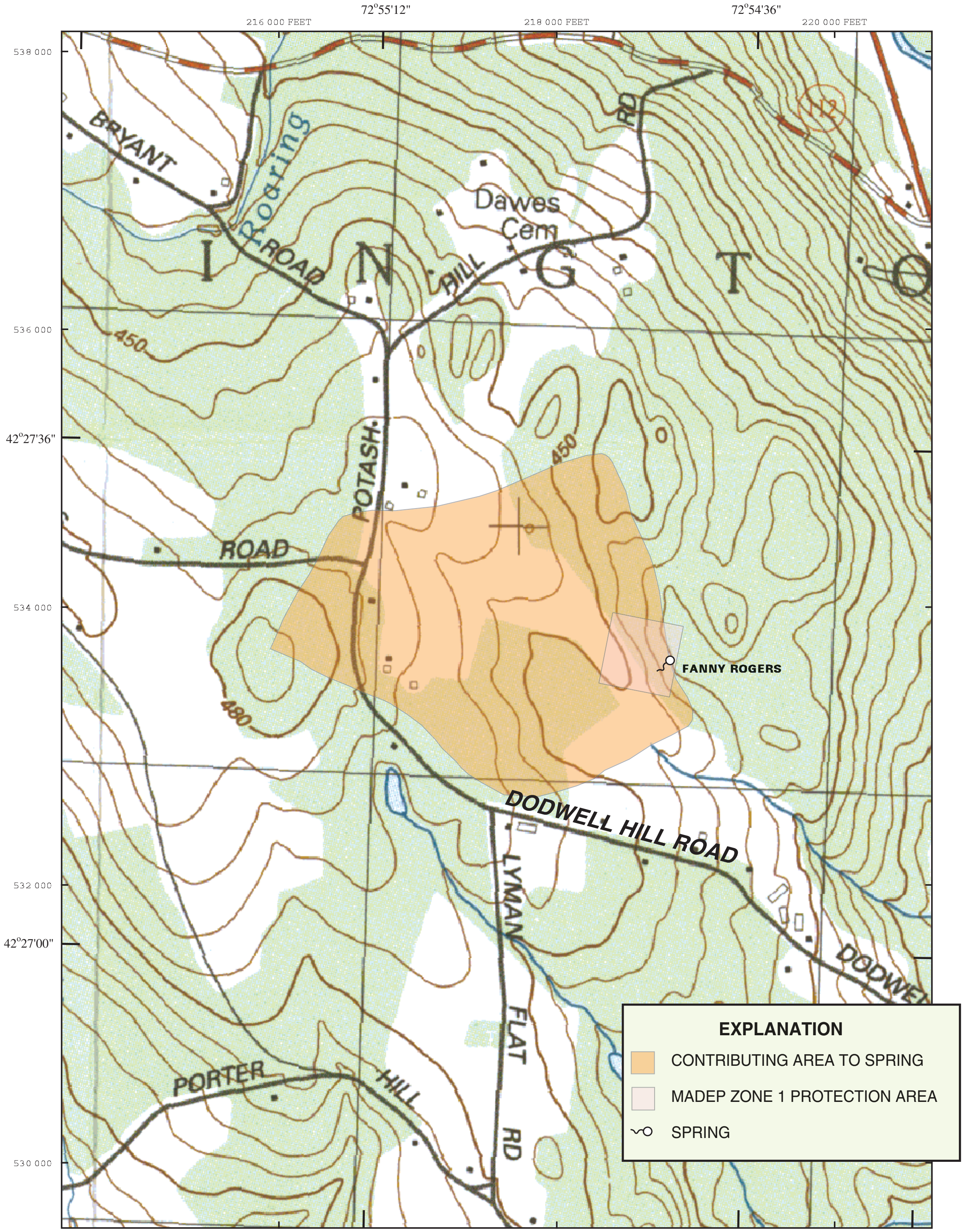


Figure 9. Record of daily maximum overflow discharge from Red Mill Spring, Clarksburg, Massachusetts, April 25 to November 13, 2002.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

0 200 400 600 800 1,000 FEET
0 100 200 METERS

Figure 10. Fanny Rogers Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Cummington, Massachusetts.

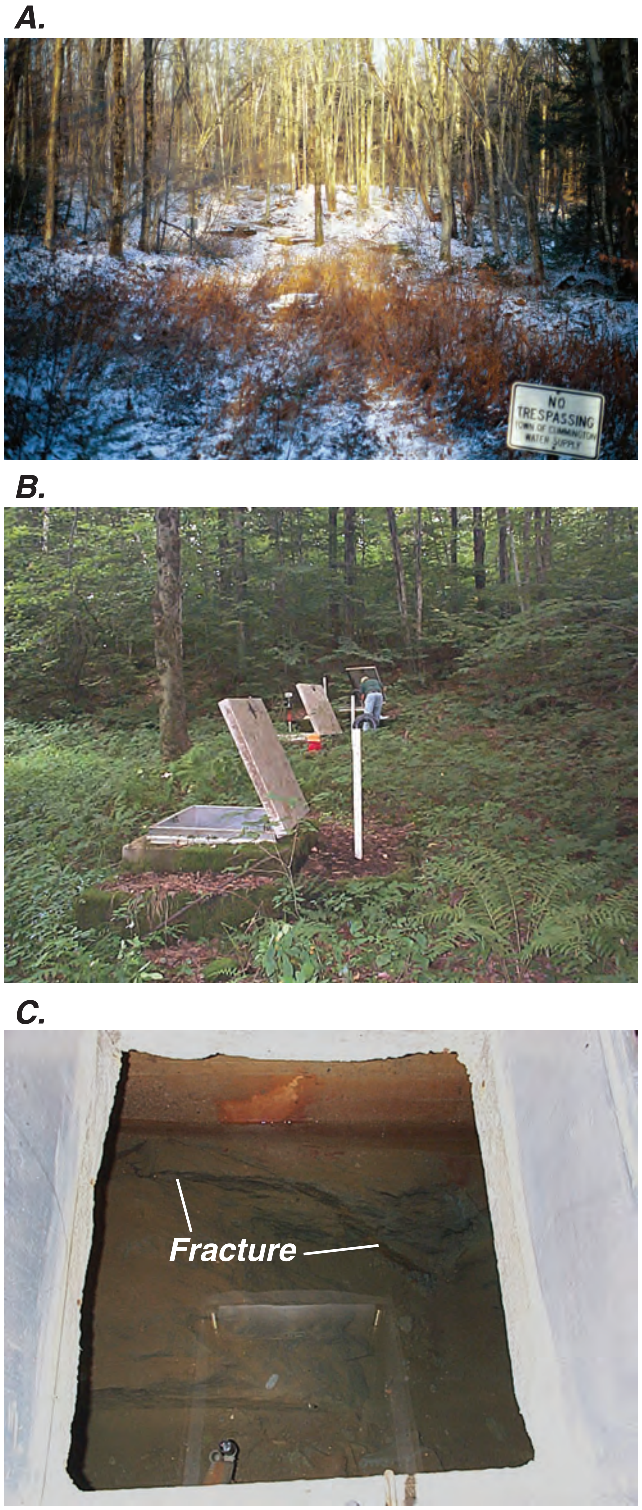
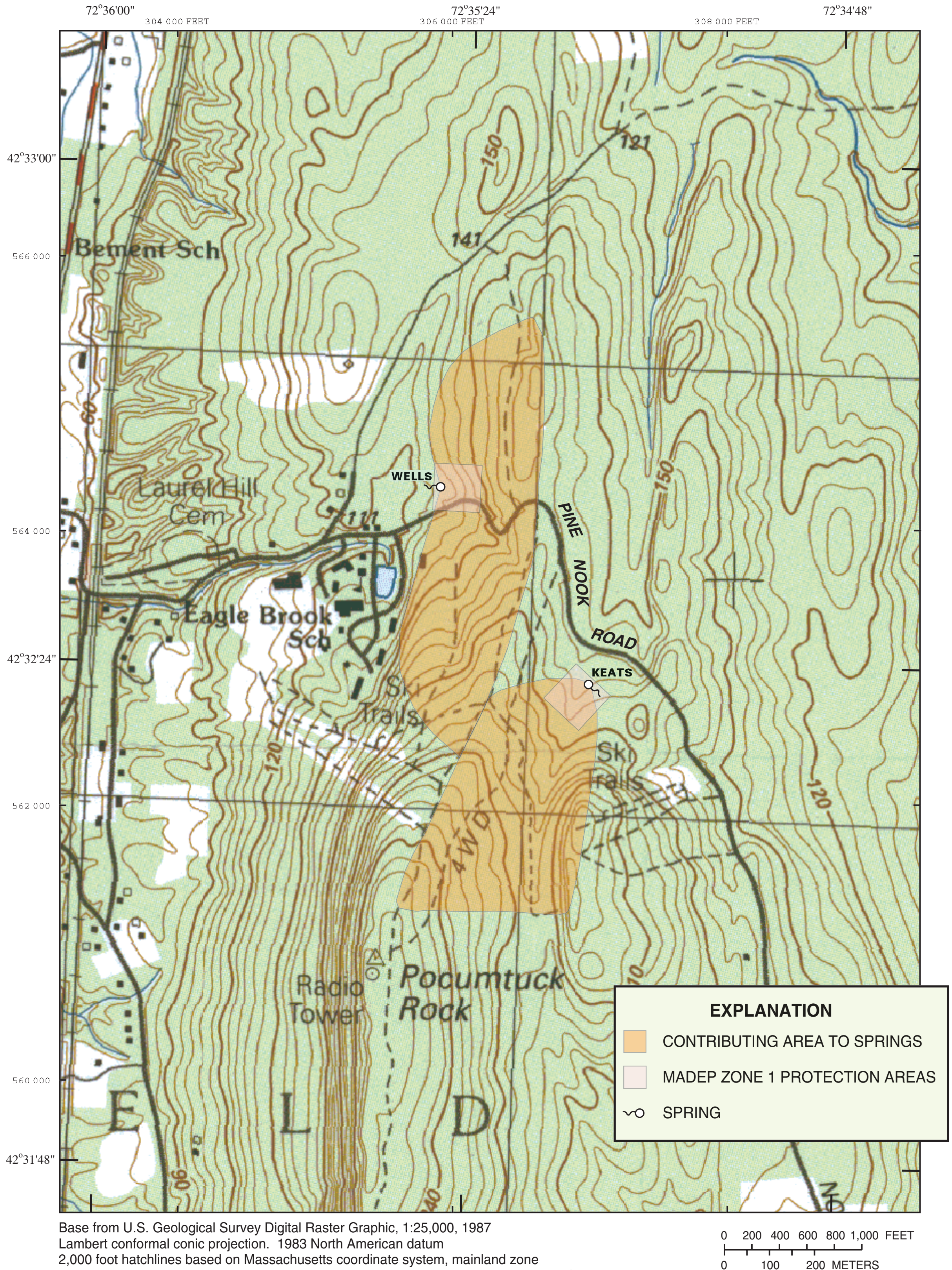


Figure 11. Fanny Rogers Spring in Cummington, Massachusetts showing *A*, three springs at top and collection cistern at center, northwestward view (photograph by Paul Blain, Massachusetts Department of Environmental Protection); *B*, three spring structures with stainless steel covers, southwestward view; and *C*, fracture that appears to be yielding water.

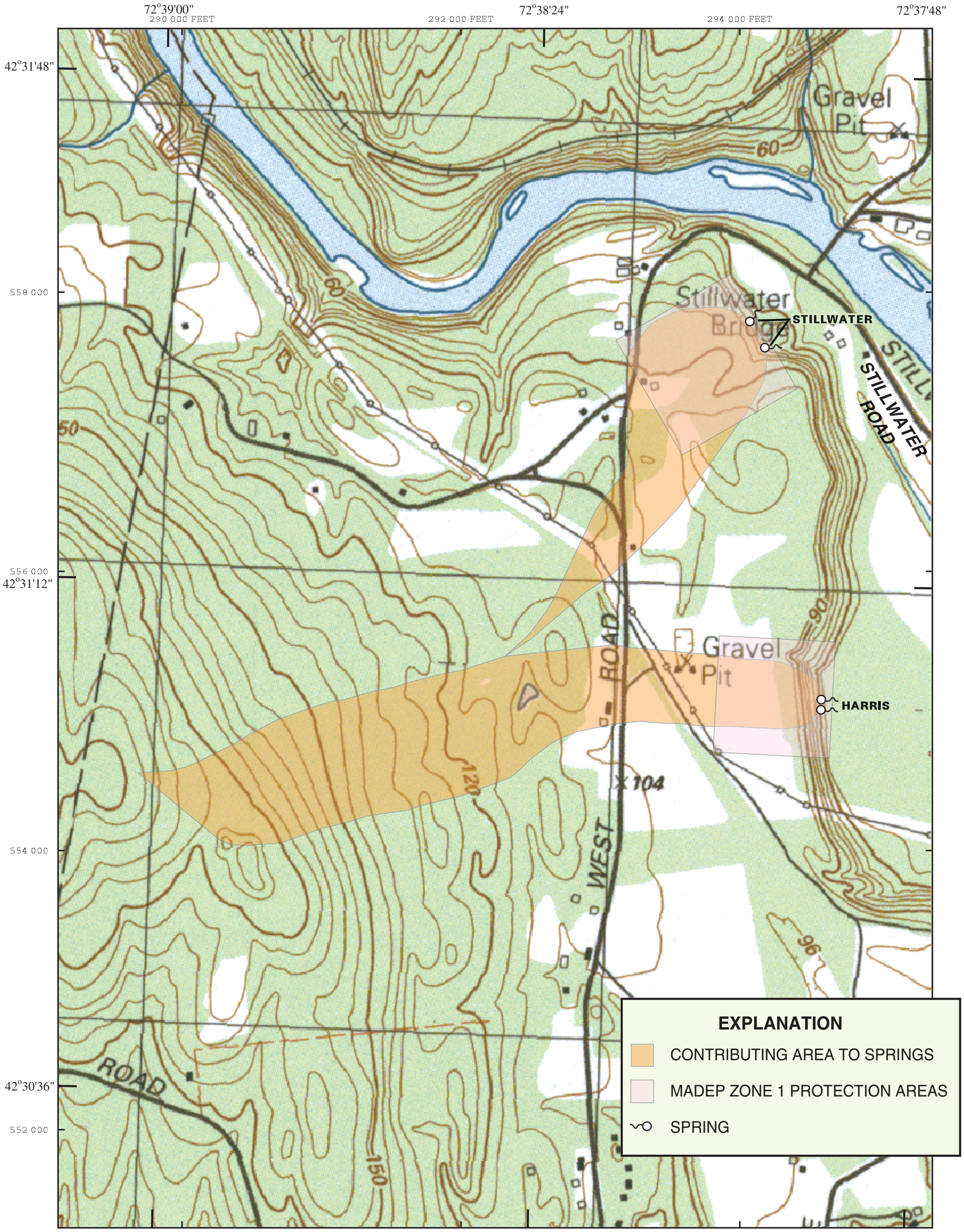


Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 12. Keats and Wells Springs, the areas contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Deerfield, Massachusetts.

Figure 13. Keats Spring in Deerfield, Massachusetts showing *A*, exterior of spring with Pine Nook Road visible in the light areas at upper center, northeastward view; and *B*, interior of stone-lined spring cistern with overflow pipe near top, eastward view.

Figure 14. Wells Spring with spring house and global-positioning-system equipment used for determining spring locations, eastward view, Deerfield, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 15. Harris and Stillwater Springs, the areas contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Areas in Deerfield, Massachusetts.

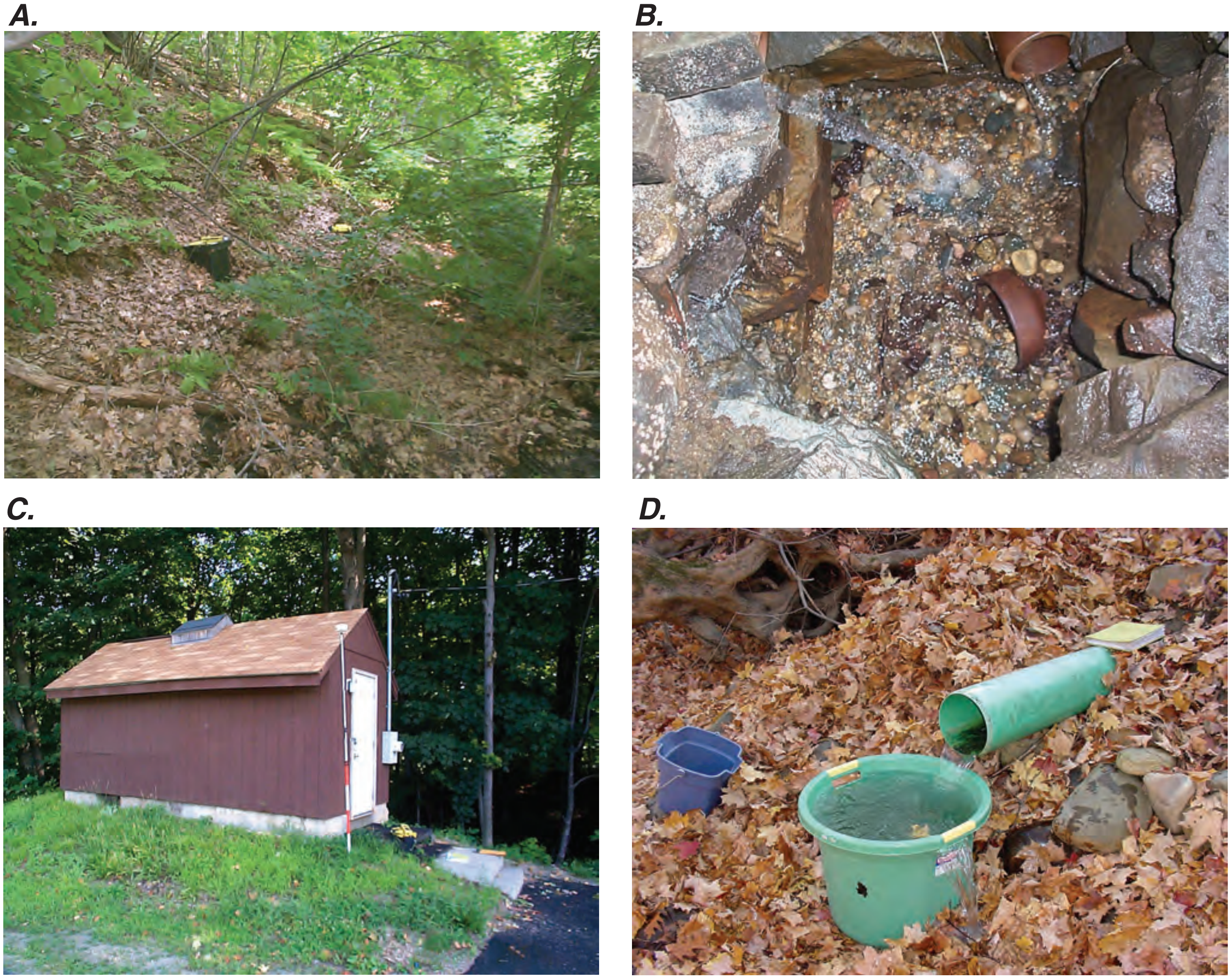
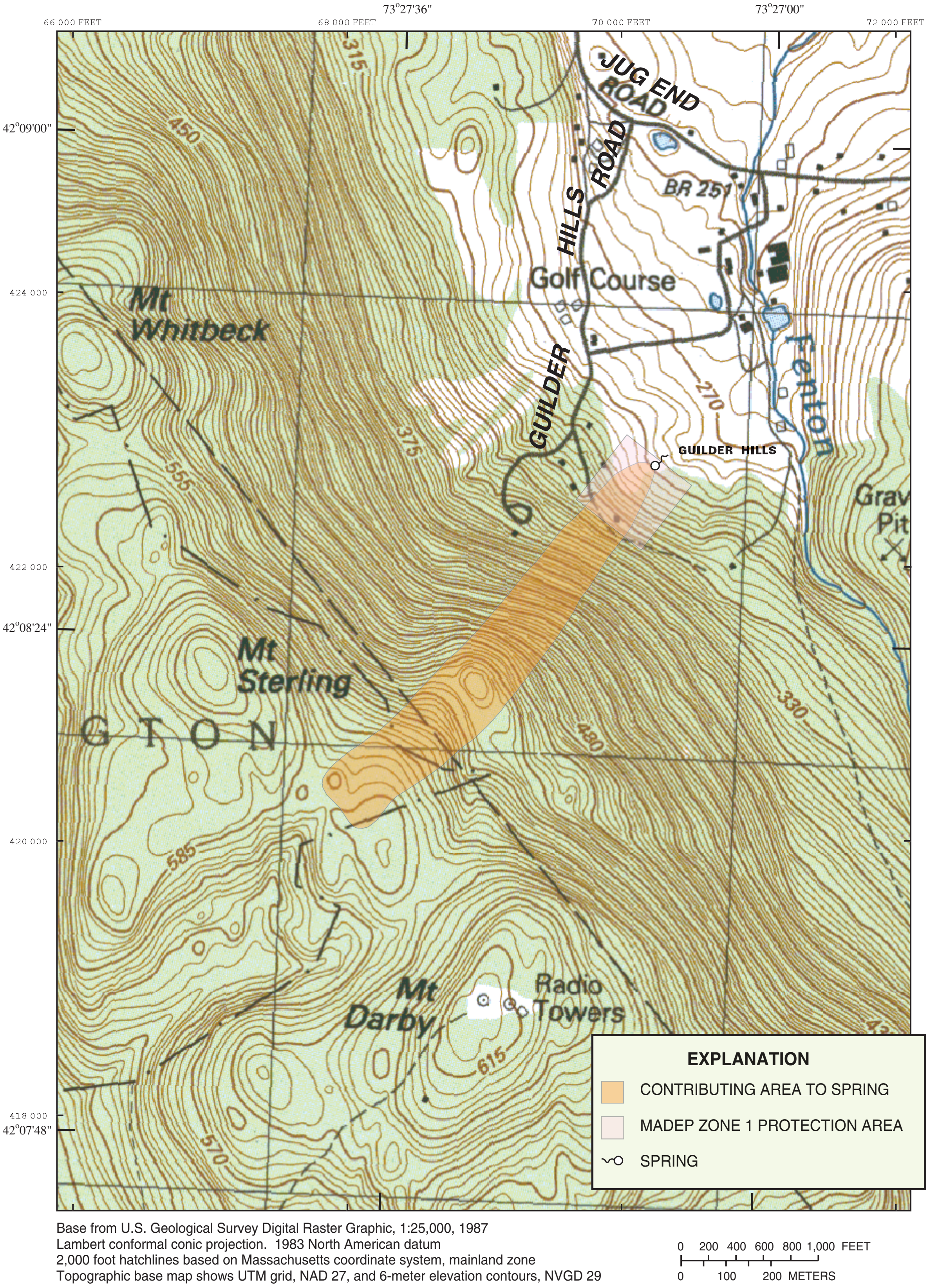


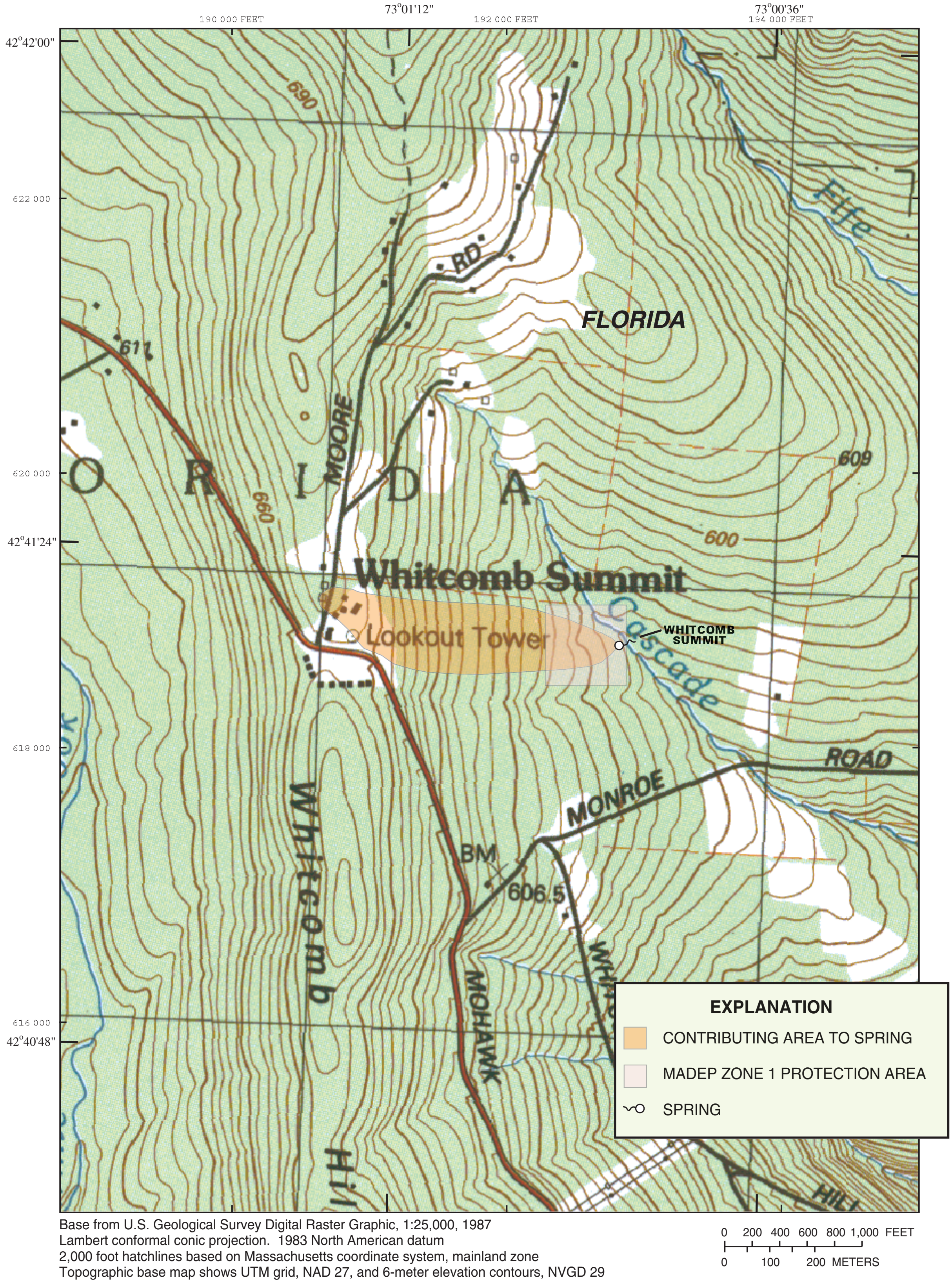
Figure 16. Stillwater and Harris Springs in Deerfield, Massachusetts showing *A*, two collection structures along the base of the scarp at Stillwater Spring, northwestward view; *B*, interior of a collection structure at Harris Spring; *C*, combined reservoir and pump house, northward view; and *D*, measuring combined discharge.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 17. Guilder Hills Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Egremont, Massachusetts.

Figure 18. Guilder Hills Spring with combined collection structure, reservoir, and pump house, northward view, Egremont, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

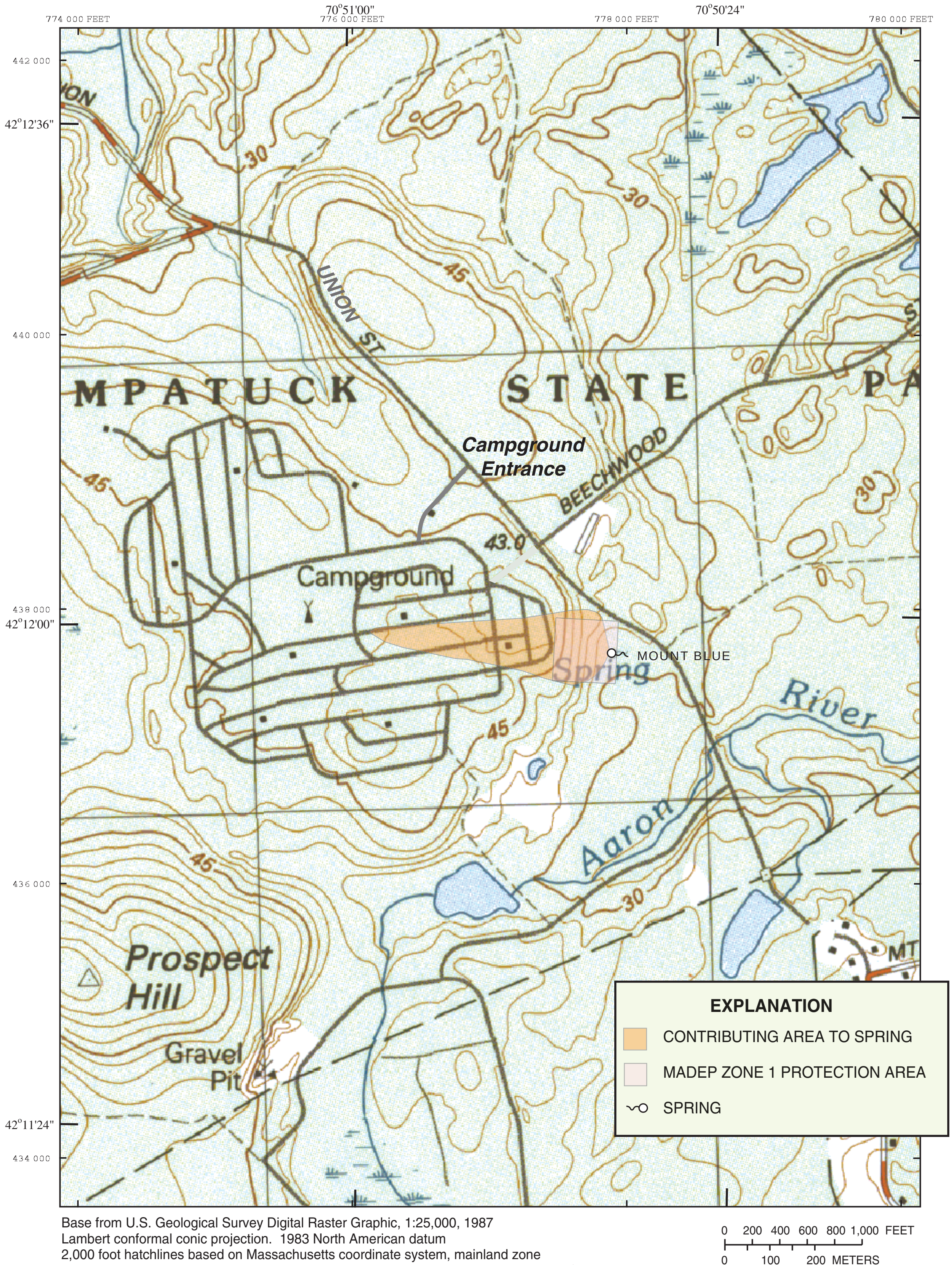
Figure 19. Whitcomb Summit Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Florida, Massachusetts.

Figure 20. Whitcomb Summit Spring in Florida, Massachusetts, showing *A*, collection structure, southwestward view; and *B*, steel collection tanks and pump house, northward view.

Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 21. Granville Center Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Granville, Massachusetts.

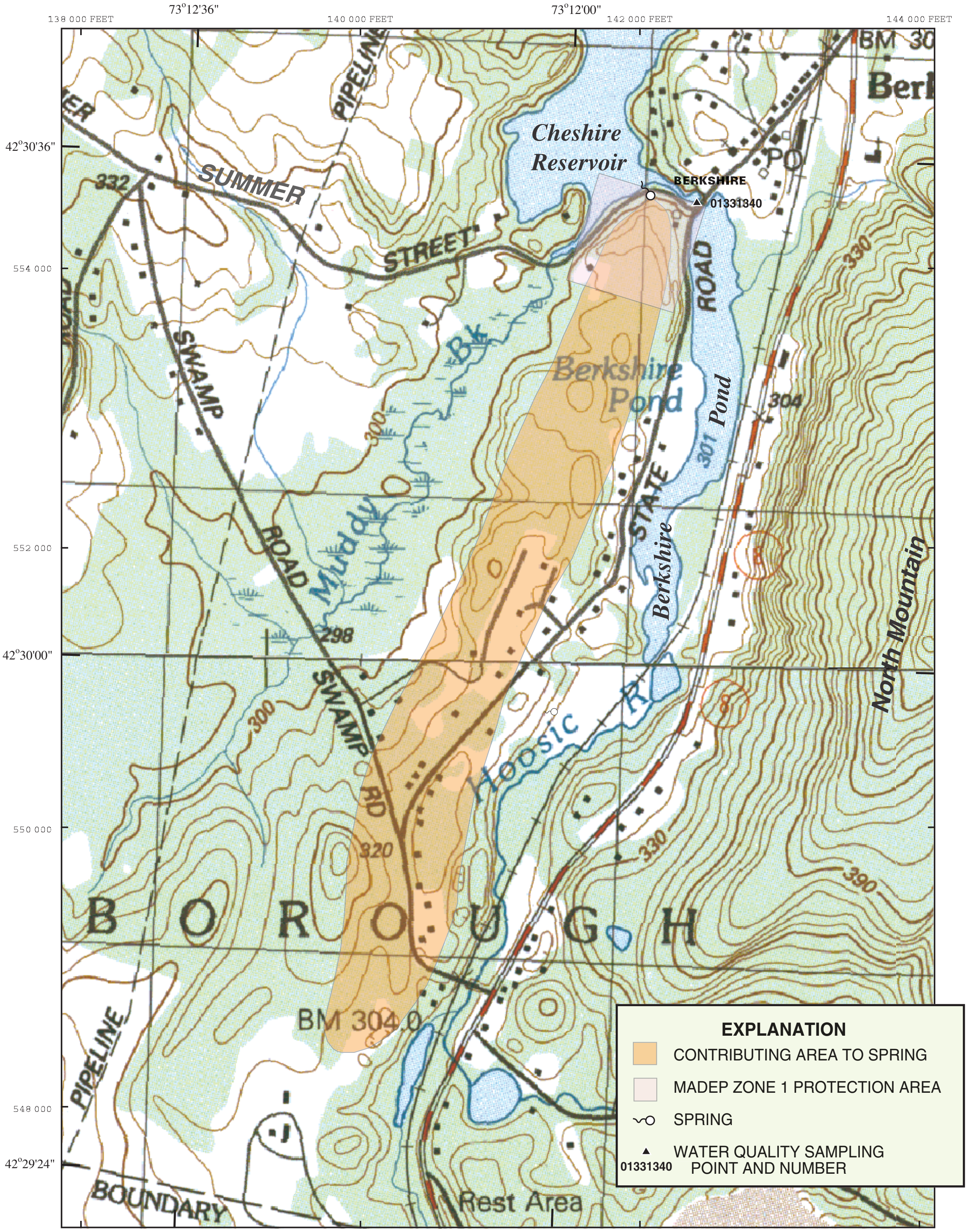
Figure 22. Granville Center Spring, northward view, Granville, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 23. Mount Blue Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Hingham, Massachusetts.

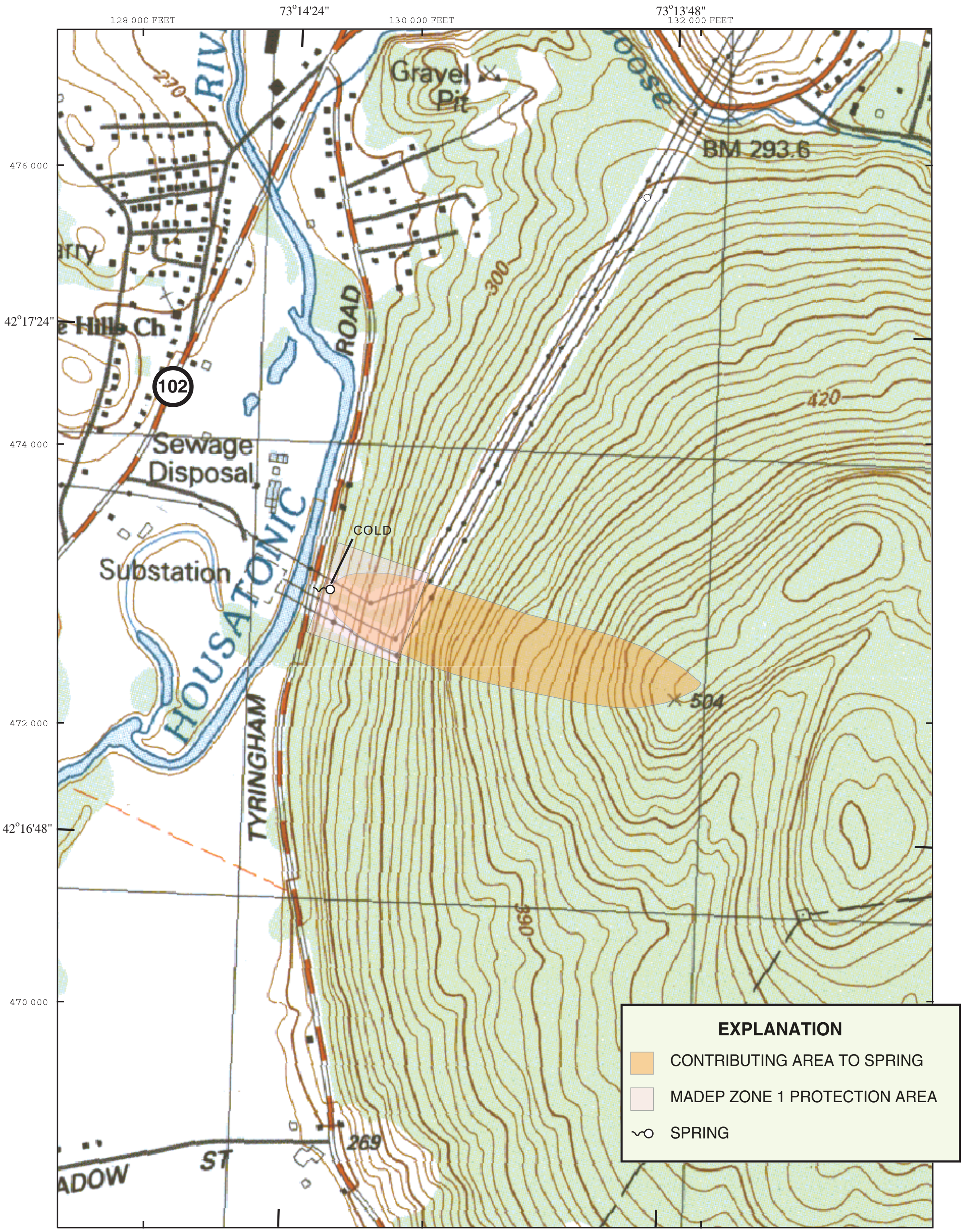
Figure 24. Mount Blue Spring, westward view, Hingham, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 25. Berkshire Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Lanesborough, Massachusetts.

Figure 26. Berkshire Spring in Lanesborough, Massachusetts, showing *A*, vault over spring, eastward view (photograph by Bruce Bouck of the Massachusetts Department of Environmental Protection); *B*, transient users filling bottles with spring water; and *C*, high-angle fractures on outcrop just east of spring, southward view.



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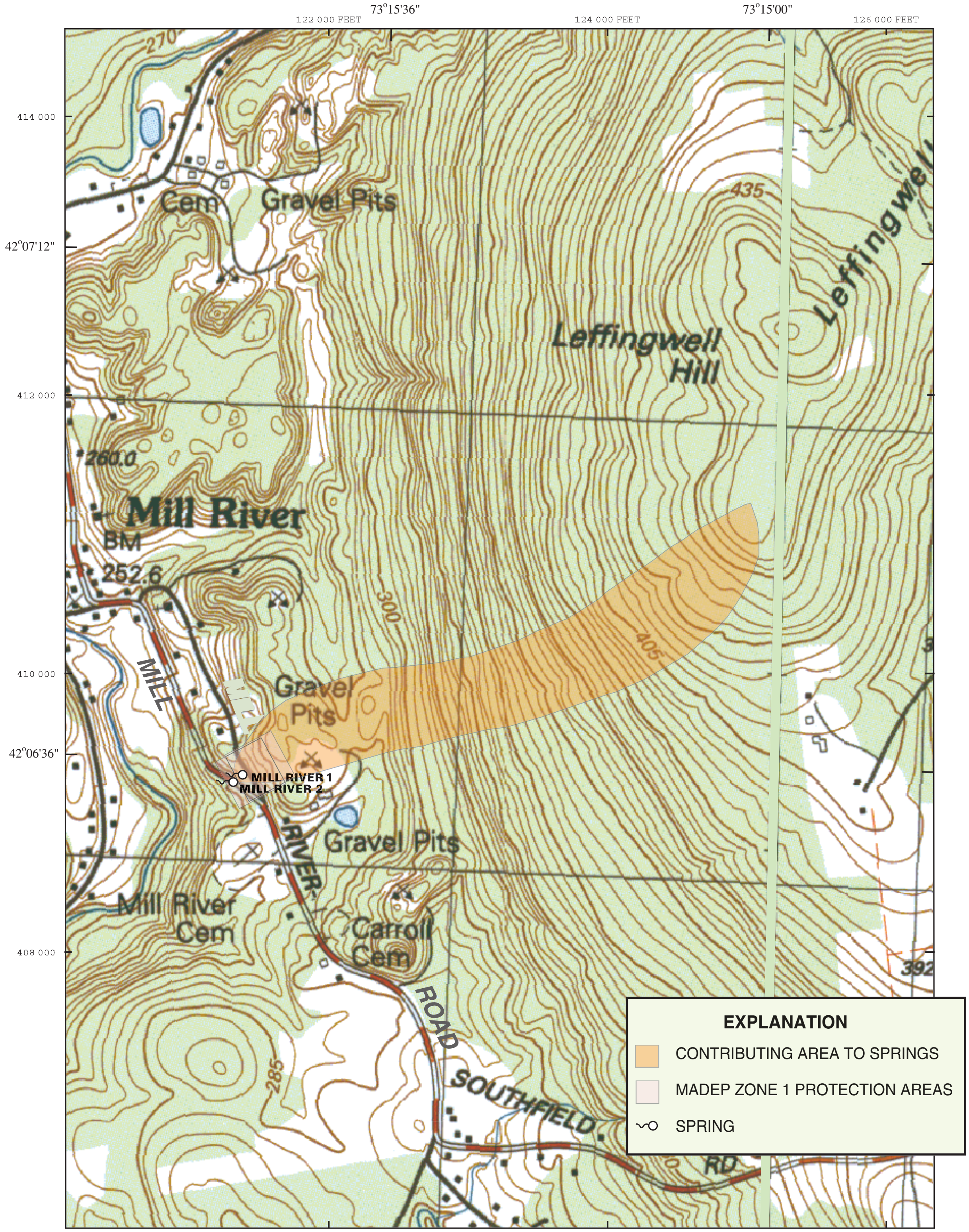
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 27. Cold Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Lee, Massachusetts.

Figure 28. Collection trough at Cold Spring, eastward view, Lee, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 29. Mill River Road Springs 1 and 2, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Areas in New Marlborough, Massachusetts.

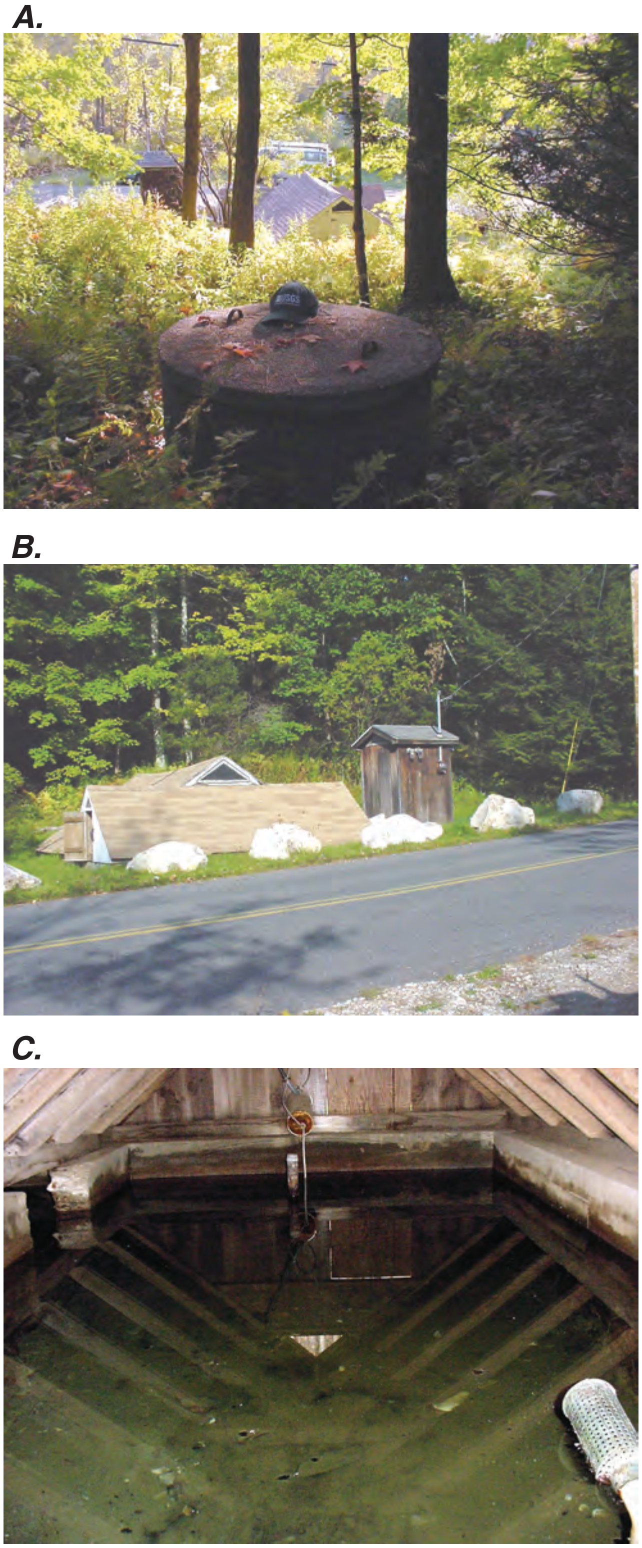
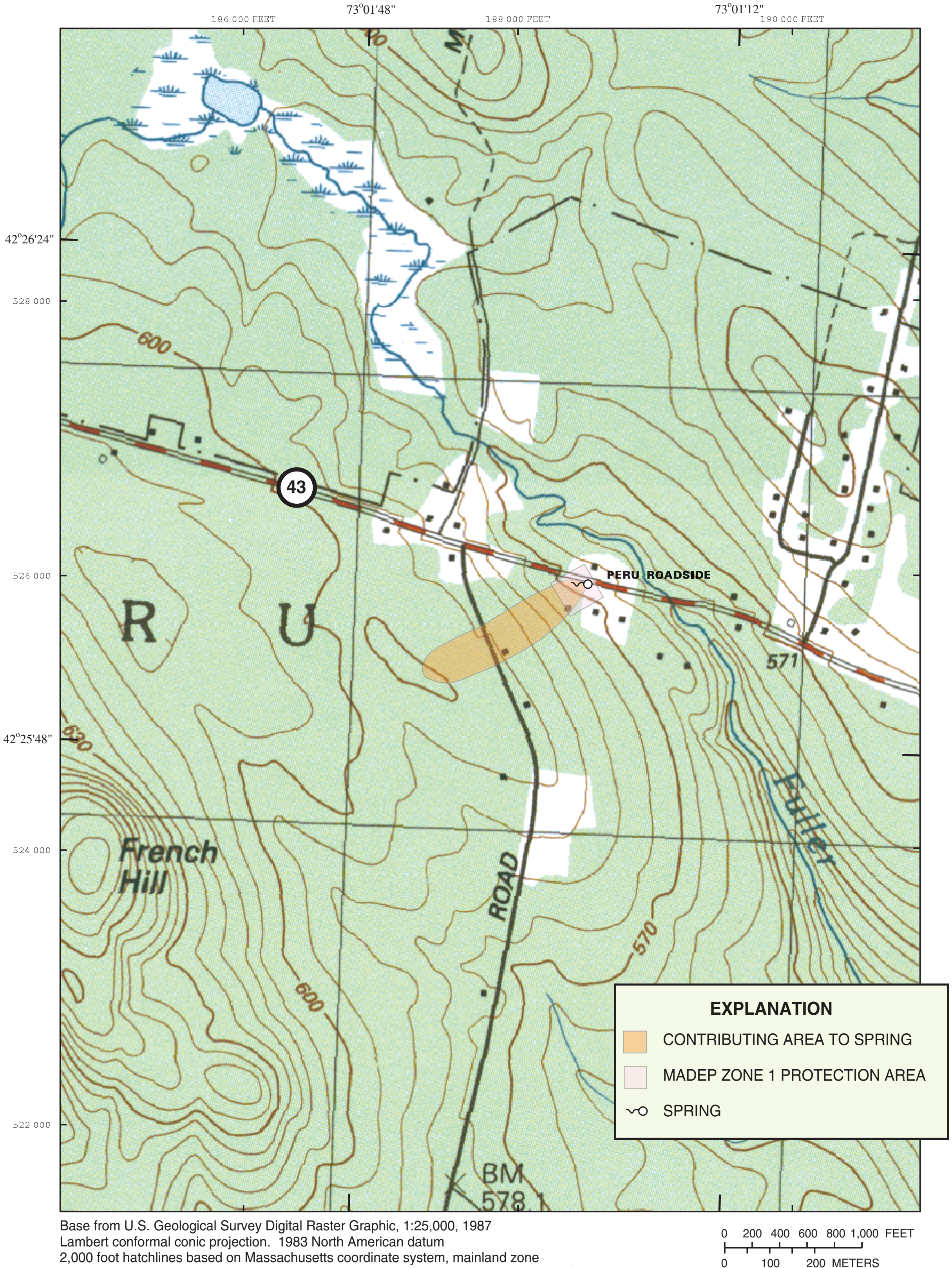


Figure 30. Mill River Road Springs 1 and 2 in New Marlborough, Massachusetts showing *A*, Spring 1 in foreground, Mill River Road and spring house covering Spring 2 in background, southwestward view; *B*, Spring 2 spring house to left and chlorination-equipment house to right, eastward view; and *C*, Spring 2 collection basin and reservoir inside spring house, southeastward view.



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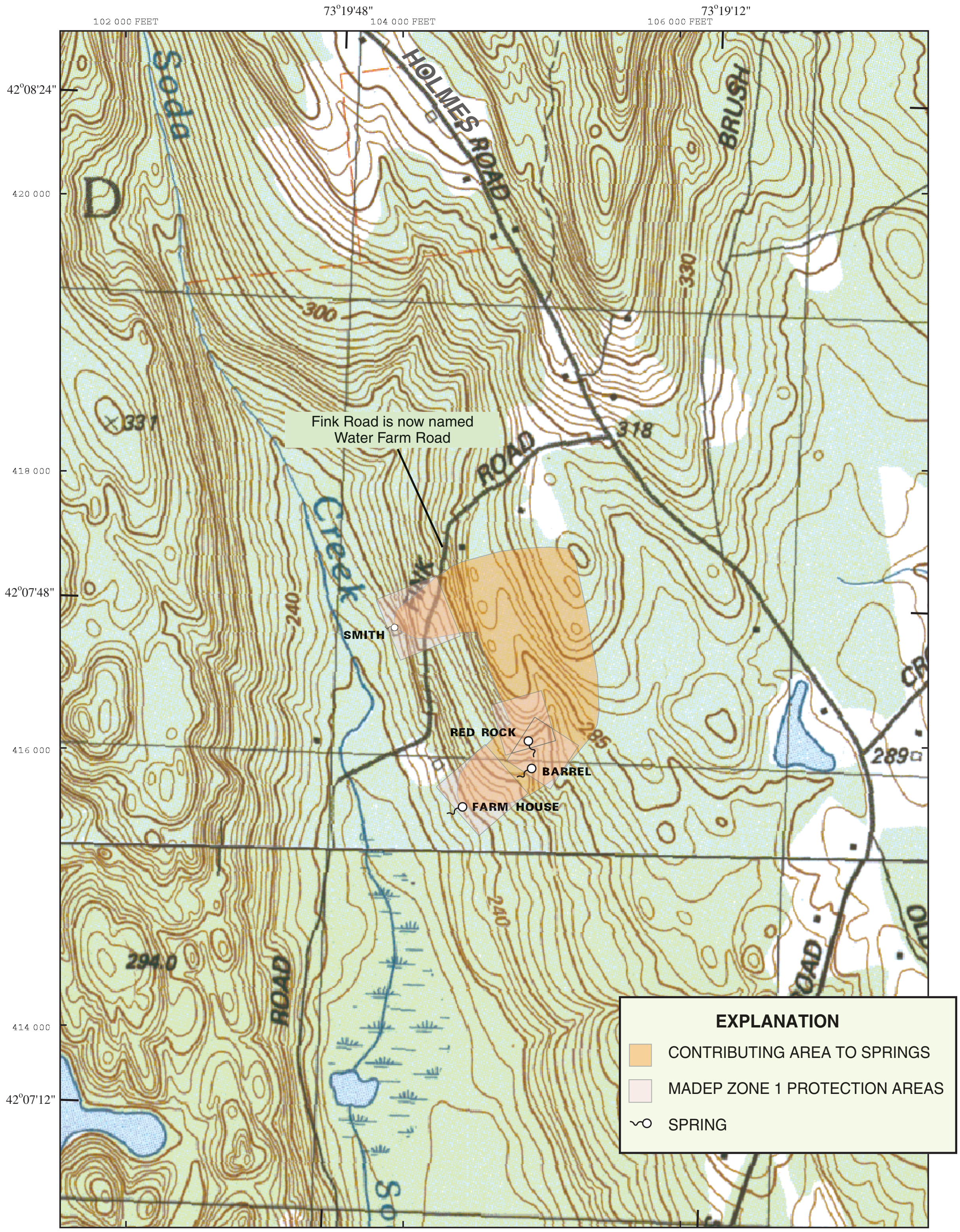
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 31. Peru Roadside Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Peru, Massachusetts.

Figure 32. Peru Roadside Spring, southward view, Peru, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 33. Farm House, Red Rock, Barrel, and Smith Springs, the areas contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Areas in Sheffield, Massachusetts.

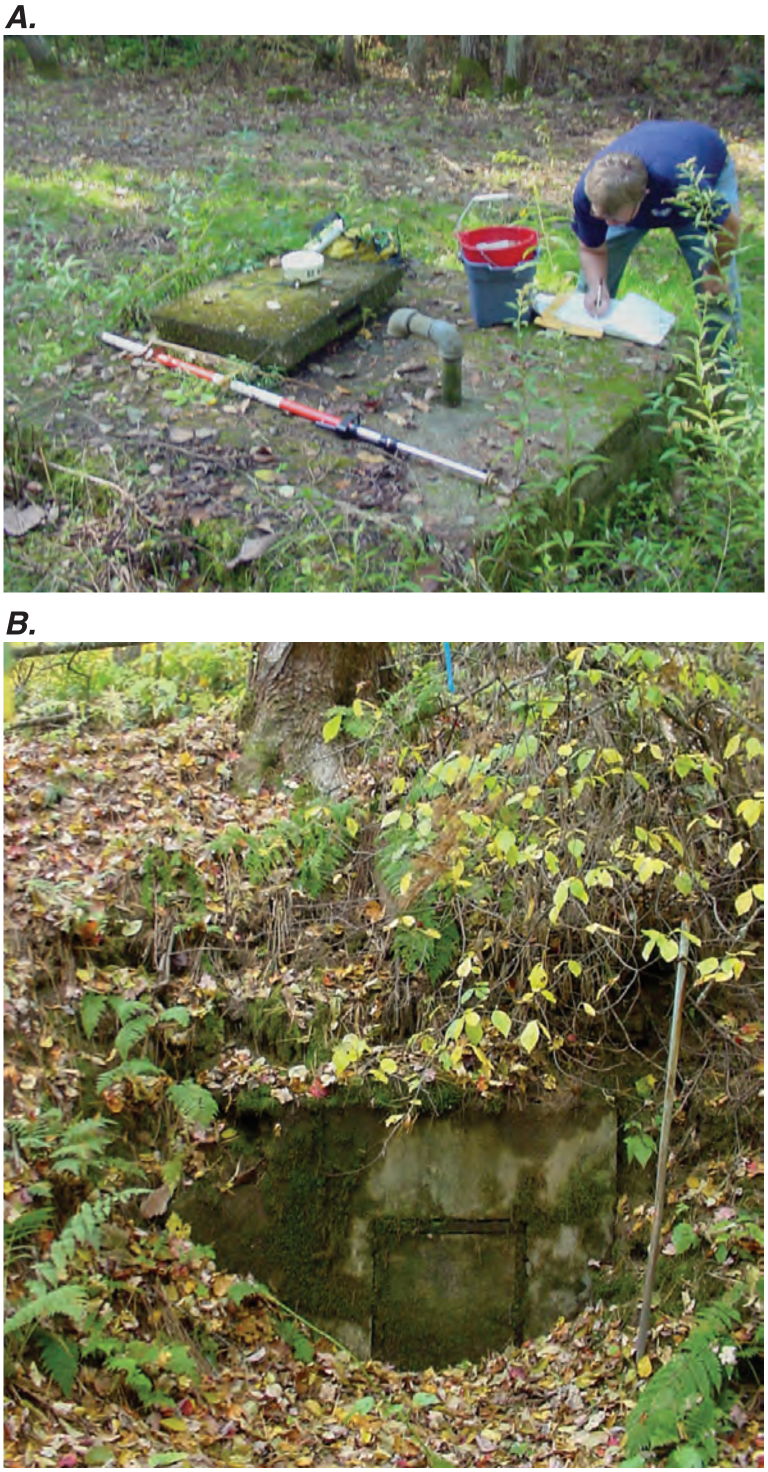


Figure 34. *A*, Farm House Spring, northwestward view; *B*, Red Rock Spring, northward view, all in Sheffield, Massachusetts.

Figure 34—Continued. *C*, interior of Red Rock Spring house with discharge pipe; *D*, Barrel Spring, all in Sheffield, Massachusetts.

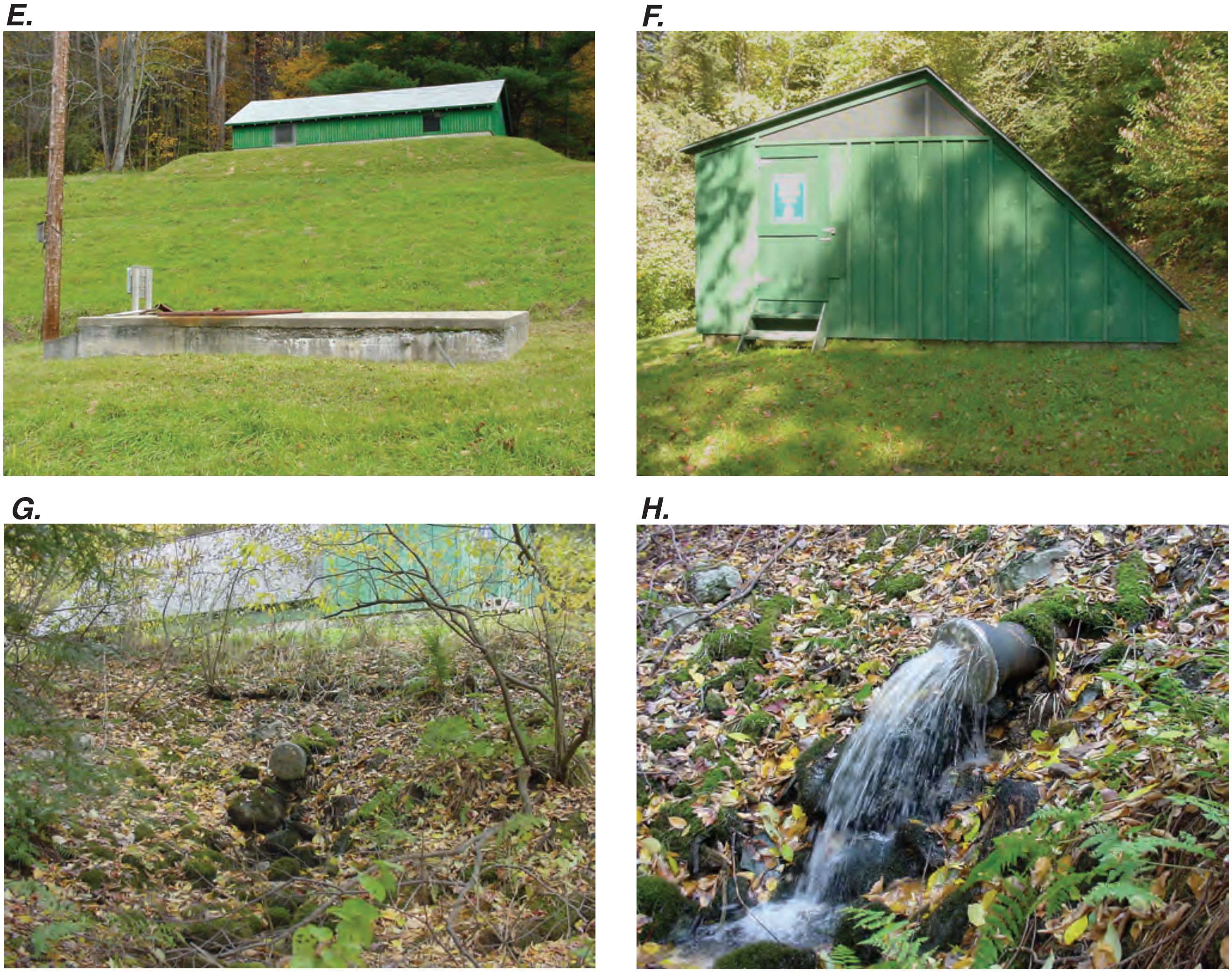
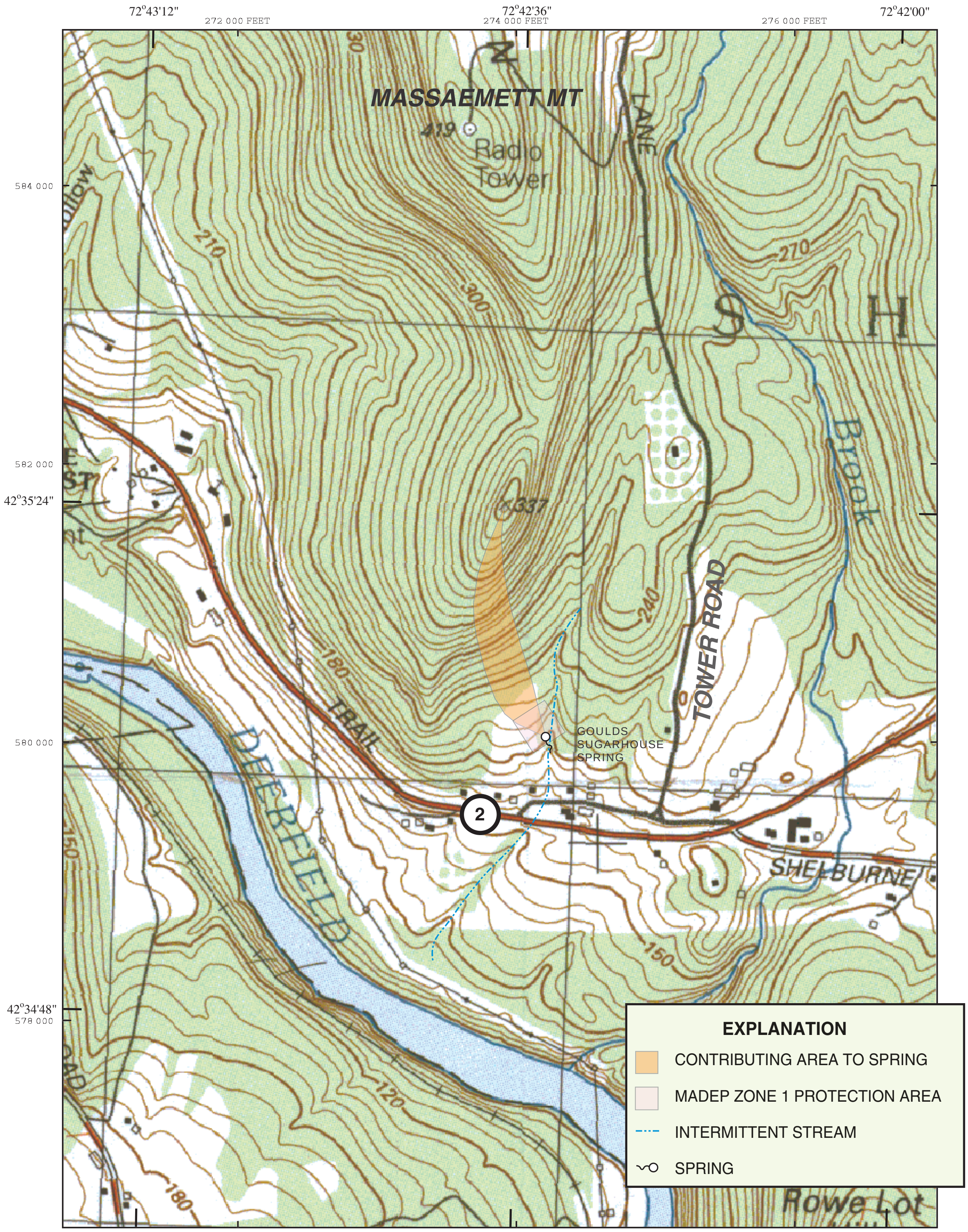


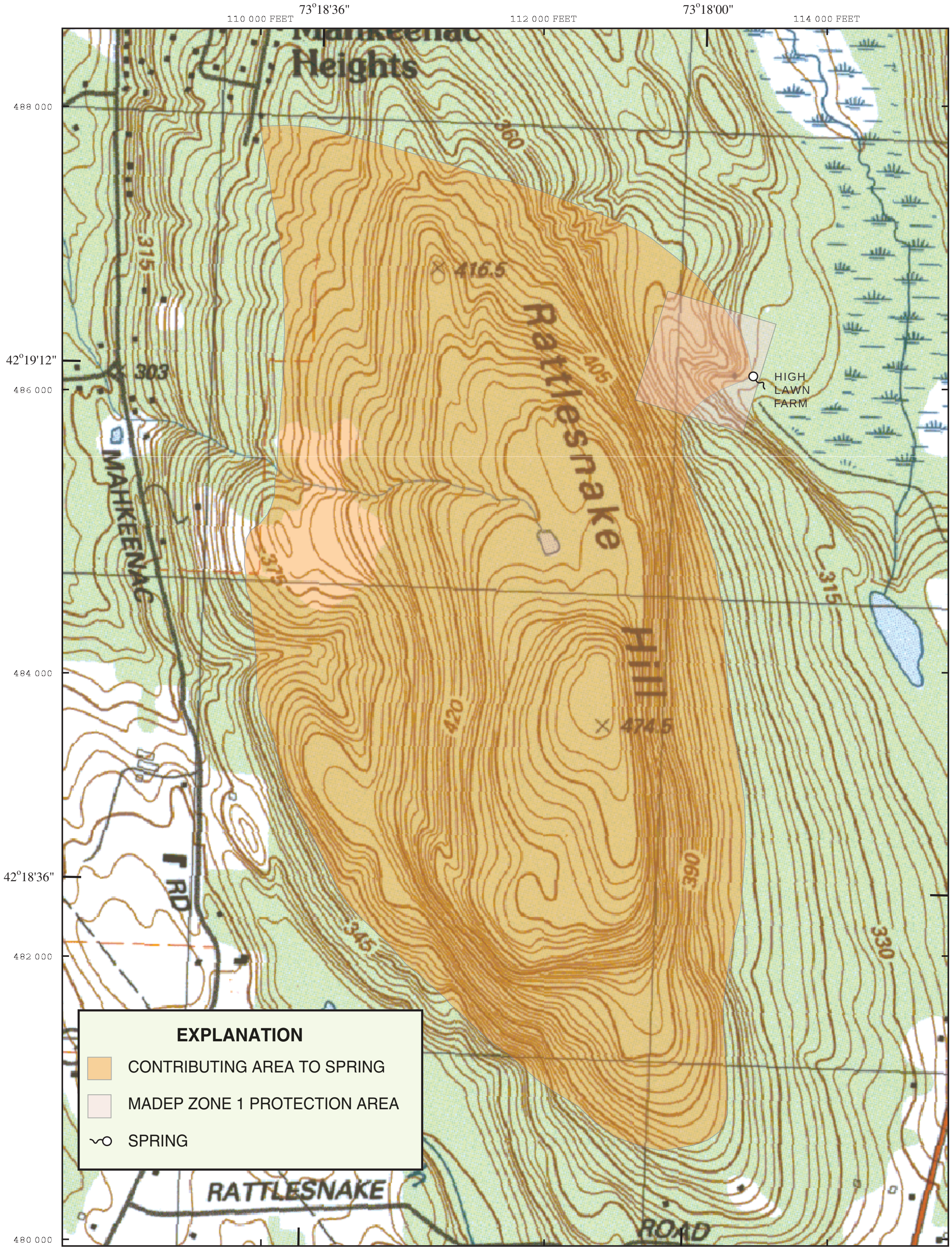
Figure 34—Continued. *E*, vault containing Farm House Spring reservoir and pump station in foreground and reservoir for Barrel and Red Rock Springs in background, northeastward view; *F*, Smith Spring House, northwestward view; *G*, Smith Spring overflow pipe, northward view; and *H*, Smith Spring overflow, northeastward view, all in Sheffield, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 35. Goulds Sugarhouse Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Shelburne, Massachusetts.

Figure 36. Goulds Sugarhouse Spring, northward view, Shelburne, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 37. High Lawn Farm Spring, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Area in Stockbridge, Massachusetts.

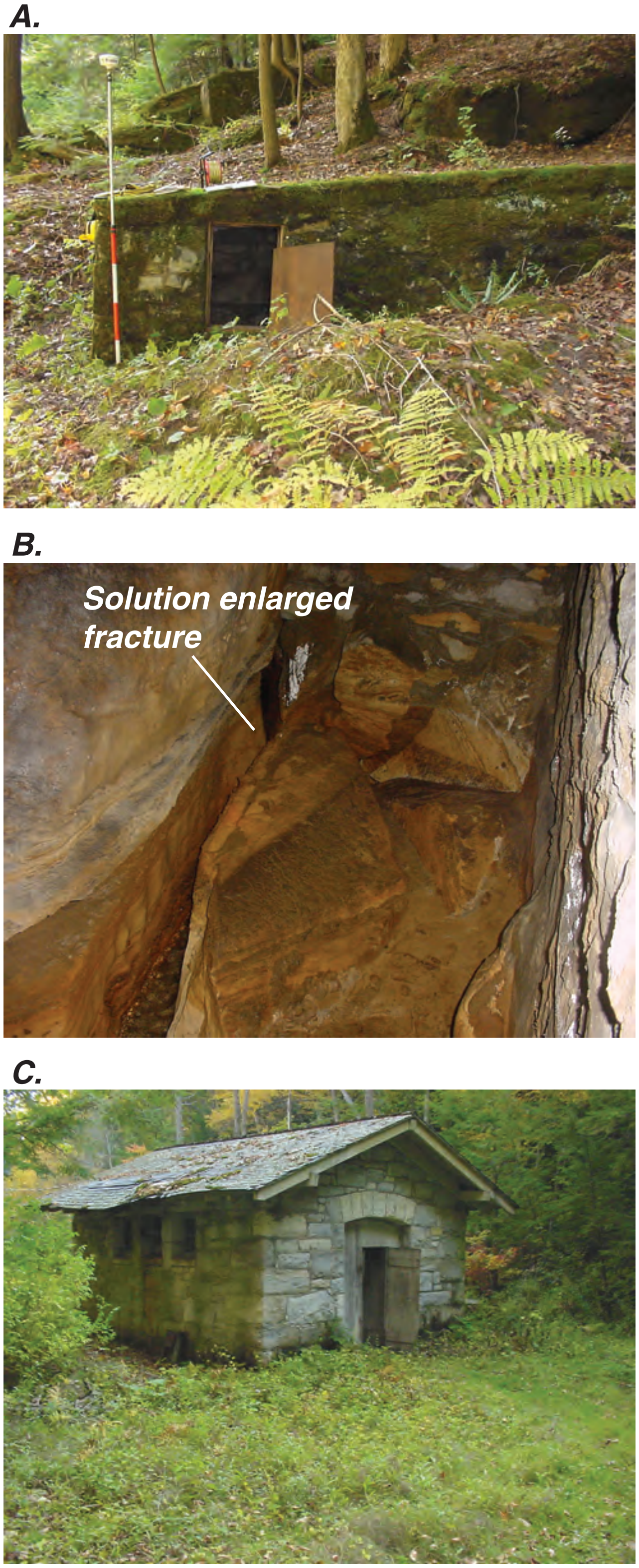
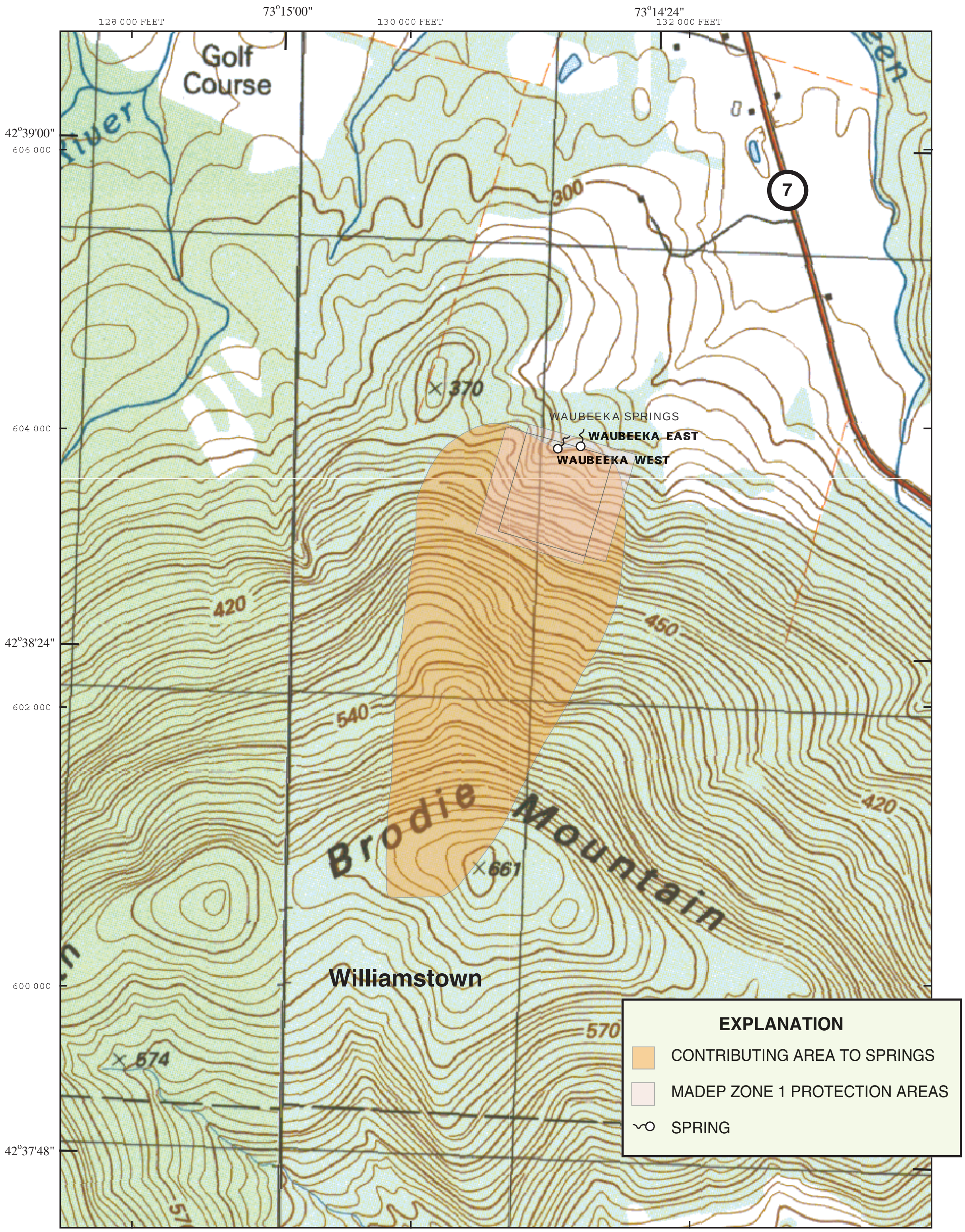


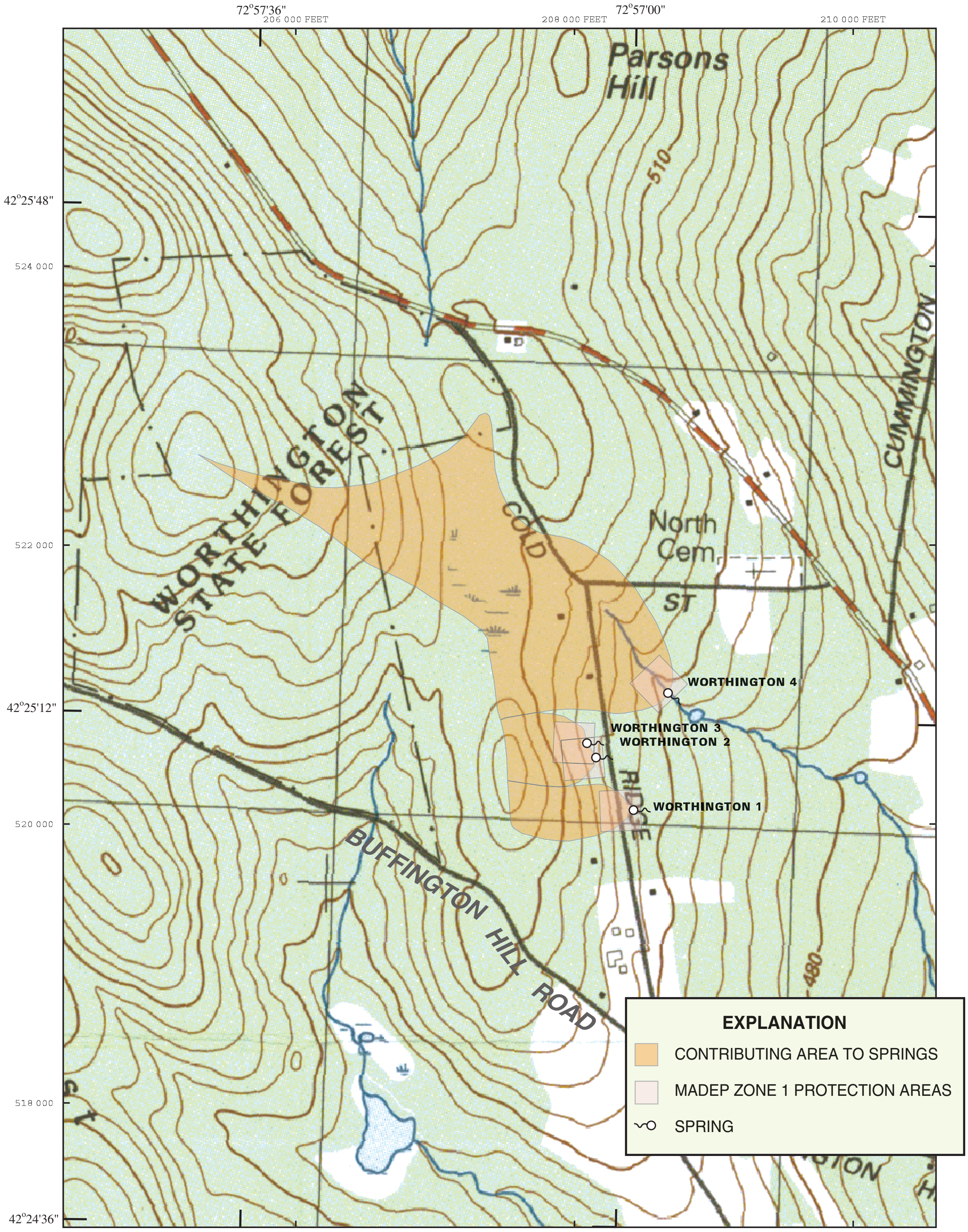
Figure 38. High Lawn Farm Spring in Stockbridge, Massachusetts, showing *A*, spring house, southward view; *B*, solution-enlarged fracture yielding water to spring, westward view; and *C*, pump house, southeastward view.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 39. Waubeeka Springs, the area contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Areas in Williamstown, Massachusetts.

Figure 40. Waubeeka Spring in Williamstown, Massachusetts, showing *A*, spring collection structure, northward view (photograph by Bruce Bouck, Massachusetts Department of Environmental Protection); and *B*, overflow from reservoirs, eastward view, November 2001.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

Figure 41. Worthington Fire District Springs 1–4, the areas contributing recharge, and the Massachusetts Department of Environmental Protection Zone 1 Protection Areas in Worthington, Massachusetts.
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Figure 42. Worthington Fire District Spring 2, westward view, Worthington, Massachusetts.

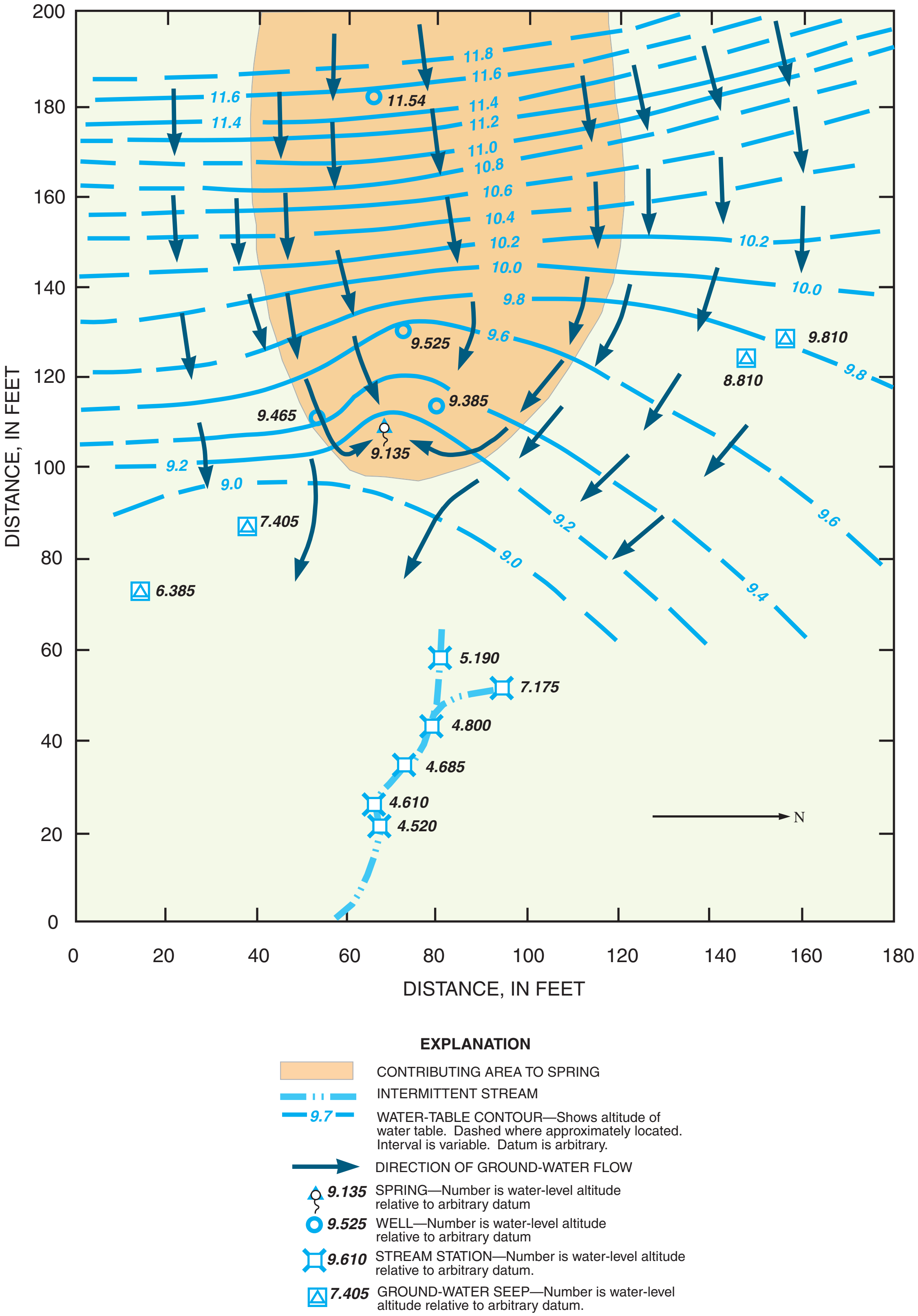
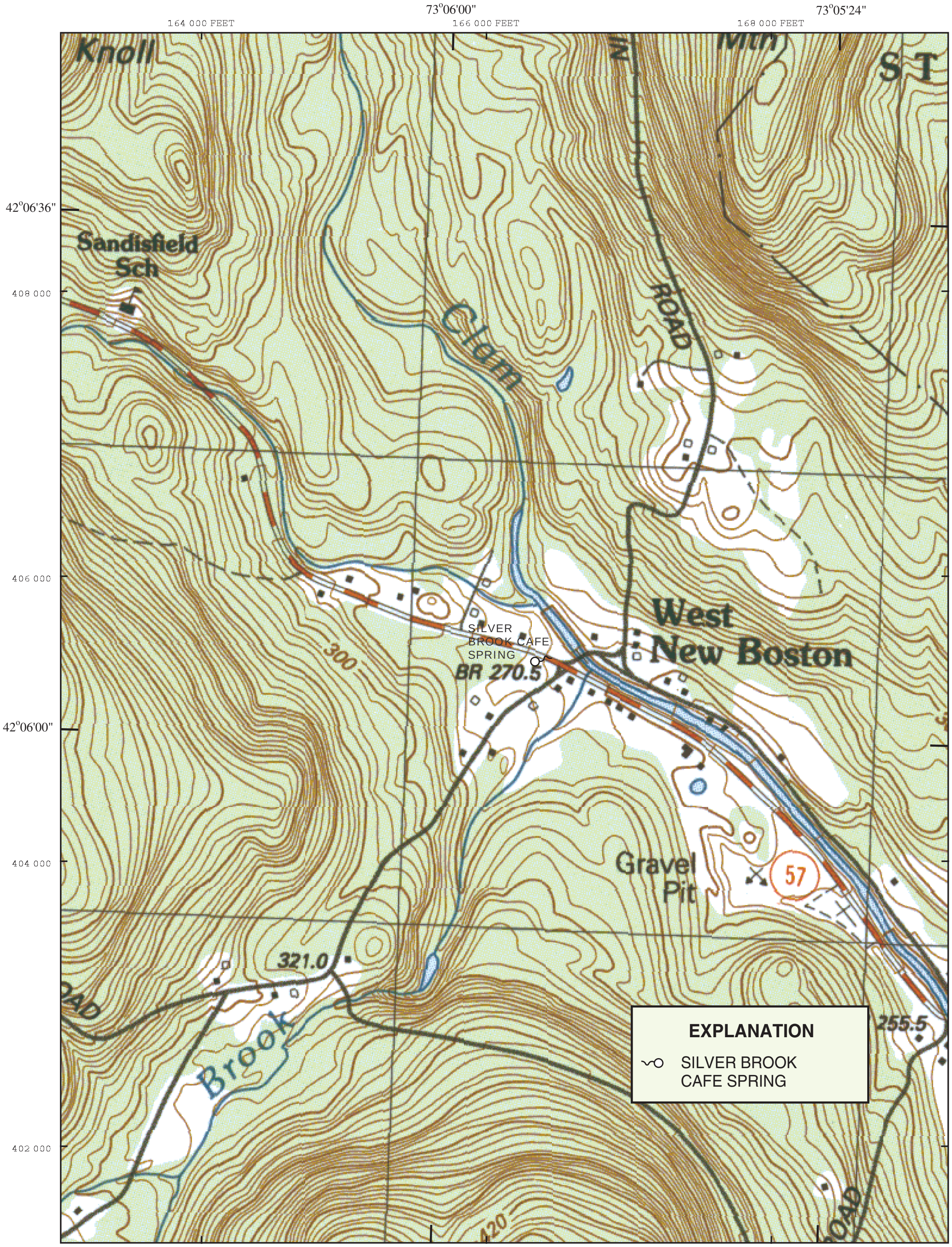


Figure 43. Water-table altitude, ground-water-flow direction, and part of the area contributing recharge to Mount Blue Spring in Hingham, Massachusetts.



Base from U.S. Geological Survey Digital Raster Graphic, 1:25,000, 1987
Lambert conformal conic projection. 1983 North American datum
2,000 foot hatchlines based on Massachusetts coordinate system, mainland zone
Topographic base map shows UTM grid, NAD 27, and 6-meter elevation contours, NVGD 29

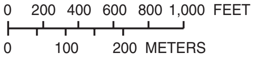


Figure 44. Silver Brook Café Spring in Sandisfield, Massachusetts.

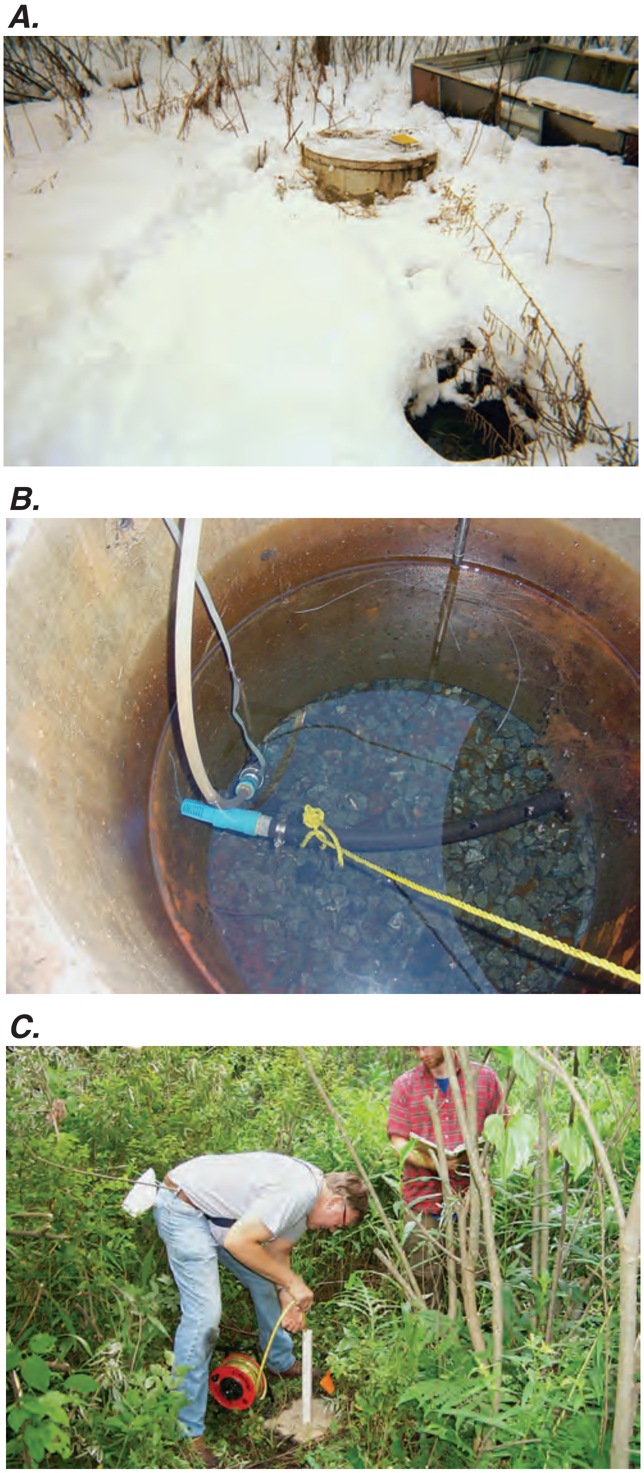


Figure 45. Silver Brook Café water source in Sandisfield, Massachusetts, showing *A*, collection structure at upper center and seepage melting snow at lower right, westward view (photograph by Bruce Bouck, Massachusetts Department of Environmental Protection); *B*, blue pump intake in collection structure; and *C*, measuring water level in small-diameter observation well.

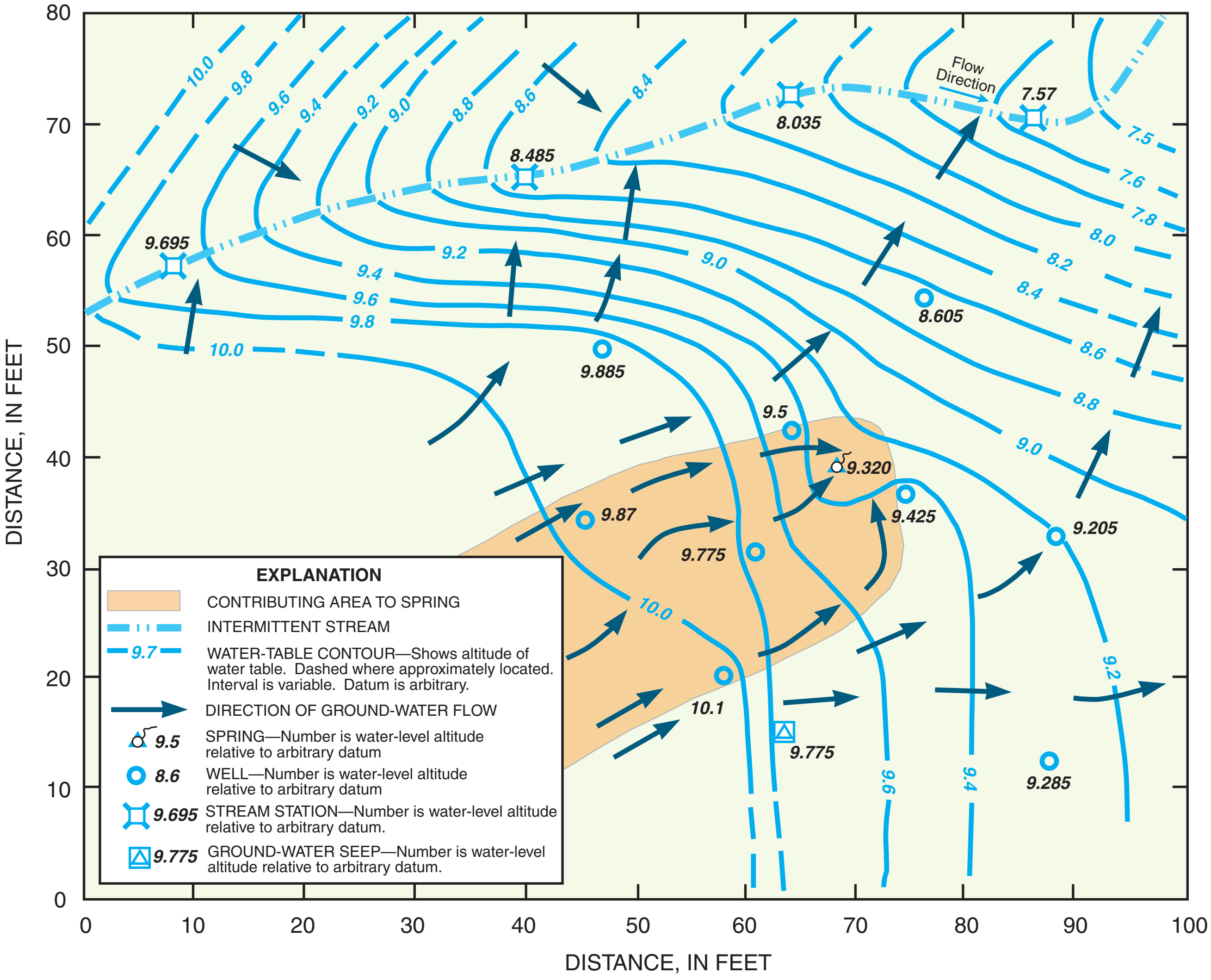


Figure 46. Water-table altitude, ground-water-flow direction, and part of the area contributing recharge to Silver Brook Cafe' Spring in Sandisfield, Massachusetts.