GROUND-WATER AVAILABILITY IN THE BARRE-MONTPELIER AREA

BY 1931-

Arthur L. Hodges, Jr. and David Butterfield

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Vermont Department of Water Resources, and
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BARRE-MONTPELIER AREA, VERMONT, 1972

ERRATA

Page 8	Line 13 - "wash borings" are EBX 1*, EBX 2
Page 8	Line 22 - "test-boring data" are EBW 47 to EBW 50
Page 11	Line 1 - "pumping-test data" is for EBW 46
Page 15	Chemical analysis is for well EBW 46. Sample collected for iron and manganese determination was on April 29, 1971.
Page 16	Line 4 - "wash boring" is MHX 1
	Line 13 - "wash boring" is MHX 3
Page 18	Line 8 - "wash boring" is BLX 1
Page 20	Line 17 - "8-inch test hole" is well NLW 13
	Line 18 - "wash-bore holes" are NLW 9 to NLW 12
Page 24	Line 7 - "wash borings" are NLX 1 to NLX 3
Page 26	Chemical analysis is for well NLW 13
Page 27	Insert "Lockwood, Kessler and Bartlett, Inc., 1970, Seismic refraction profiling Montpelier area, Vermont. 17p.

*Local well and boring numbers used by the U.S. Geological Survey

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GROUND WATER AVAILABILITY IN THE

BARRE - MONTPELIER AREA

By

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INTRODUCTION

A study of the ground-water resources of the Barre - Montpelier area (fig. 1), Washington County, was begun in 1968 as part of a cooperative program between the Vermont Department of Water Resources and the U.S. Geological Survey. The purpose of the study is to provide technical appraisal of potential sources of water to meet the expanded needs of most towns in Washington County, as pointed out by the Rural Comprehensive Water and Sewer Plan (Vermont Department Water Resources, 1969). Funding was made available by the U.S. Department of Agriculture, Farmers Home Administration, for water-resources exploration, including the testing of the quantity and quality of the water in sand and gravel aquifers. The geology of the area was mapped, and private and municipal water supplies were inventoried in 1968.

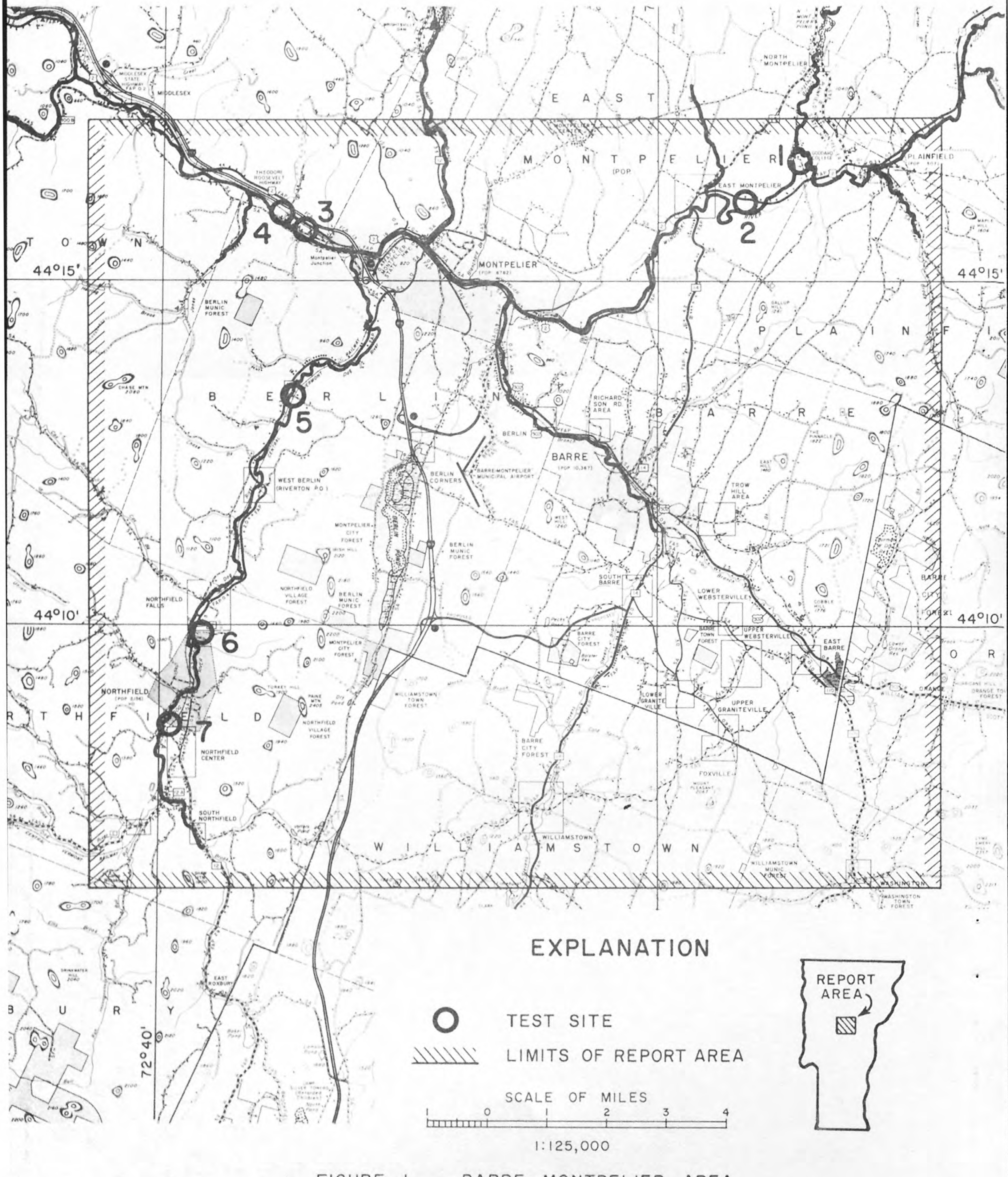

FIGURE I BARRE-MONTPELIER AREA

GEOLOGY

The Barre - Montpelier area lies wholly within the drainage basin of the Winooski River. In much of the area the valley is unsuitable for development of large supplies of ground water because it is underlain by silt and clay or bedrock at shallow depth. However, saturated sand and gravel in the valley is locally more than 80 feet thick and has potential for the development of high-capacity wells. Upland areas between the river valleys are underlain by bedrock that is covered by a variable thickness of glacial till. Most wells finished in bedrock and till yield small amounts of water, and the upland area, where this material is exposed, generally is unfavorable for the development of high-capacity wells. For this reason, exploration was limited to valleys in which thick deposits of water-bearing sand and gravel are known (Hodges, 1967).

EXPLORATION METHODS

Test work was carried out in three phases. The first was seismic refraction profiling at several locations in the Winooski and Dog River valleys to determine the shape, thickness, location, and type of materials below the valley floor. The second phase was driving wash borings, 2½ inches in diameter, to determine the permeability of the subsurface materials. Observation wells, 1¼ inches in diameter, were installed in the wash bore holes at two locations that were found to have potential for development as municipal water supplies. These small-diameter wells served as observation wells during the third phase of the program, during which an 8-inch well was constructed at each of the two locations and the aquifer tested. The two test wells, finished with 20 feet of wire-wrapped screen, were pumped until they were essentially sand-free, assuring good well efficiency during testing. After the wells were developed, each well was pumped for 48 hours, and measurements of drawdown and recovery were made in the pumping well and four observation wells.

TEST SITES AND AQUIFER TESTS

Test work was carried out at seven sites (fig. 1) within the Barre - Montpelier area.

Site 1 - East Montpelier - Plainfield town line on the properties of J. Tofani, J. E. Boudreau, and Caledonia Sand and Gravel Company (fig. 2). This site is in a broad valley at the junction of the Winooski River and Kingsbury Branch. East-west oriented seismic profiling across the former delta of the Kingsbury Branch, approximately half a mile south of the present mouth of the branch, indicated that bedrock is 45 to 120 feet below land surface, the deepest point being near the center of the valley. A short seismic profile perpendicular to this line showed that the bedrock surface slopes southward at about 10 degrees. Wash borings on the east-west seismic line showed that the east and central part of the valley are underlain by relatively impermeable lacustrine silt and clay. The west side of the valley, however, is occupied by an esker containing permeable gravel that extends far enough below the water table to constitute a good aquifer. Much of the sand and gravel above the water table has been removed from the core of the esker, and several water-filled pits have been produced by removing gravel from below the water table. Seismic and test-boring data indicate that the coarse sand

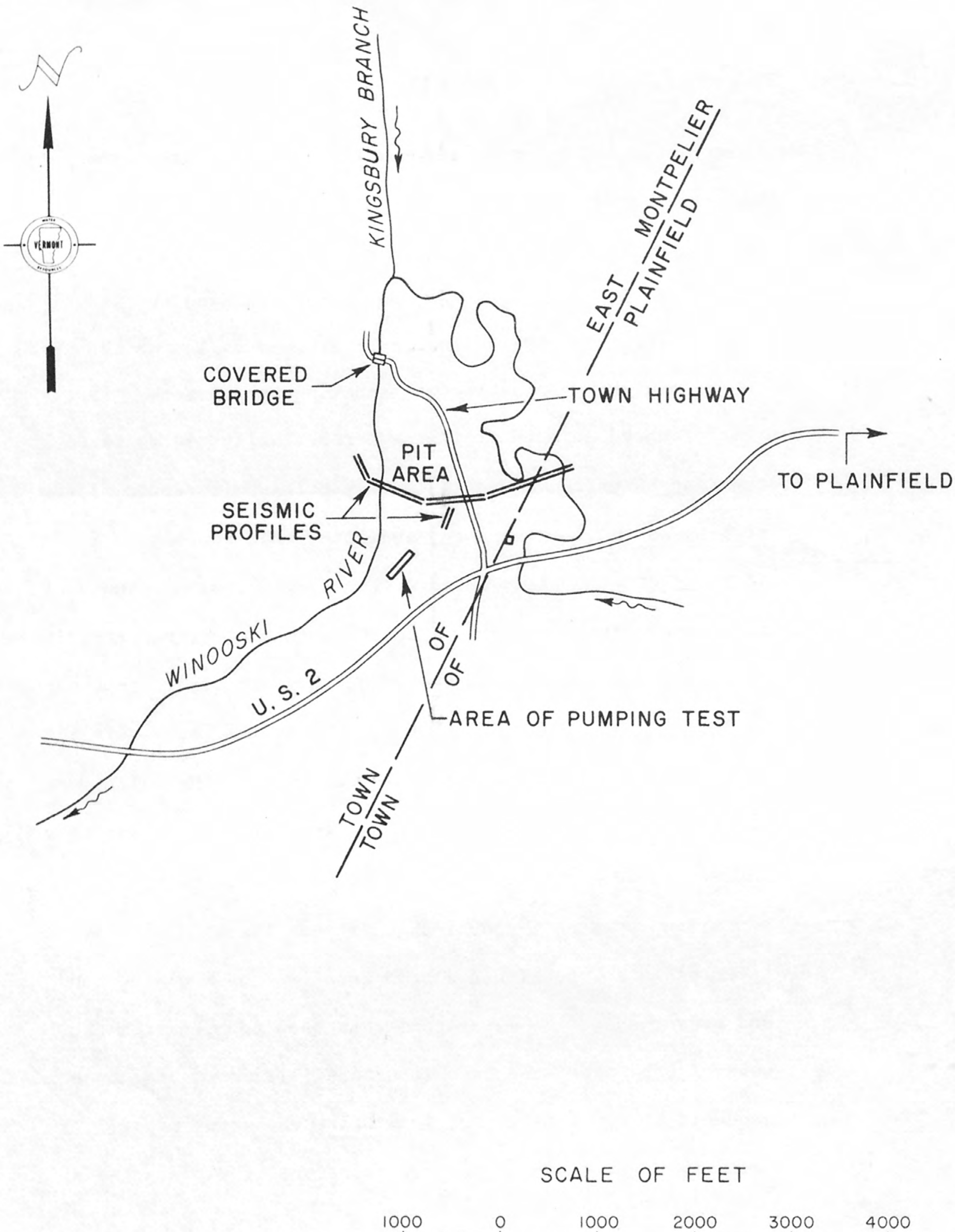

FIGURE 2 TEST SITE 1

and gravel of the esker is probably less than 800 feet wide and 60 feet deep at the mouth of Kingsbury Branch. The thickness of this material increases to the southwest in the valley of the Winooski River. The width of the coarse material to the southeast of the test site is estimated to be at least 600 feet. Farther to the southwest, several privately owned gravel wells indicate that this aquifer extends toward the town of East Montpelier. A gravel pit on the south bank of the Winooski River upstream from East Montpelier may have been dug in a remnant of the esker. Fine sand, silt, and clay flank the esker to the south and east of the test site, and, to the north, the Winooski River marks the boundary between the esker and bedrock.

Pumping-test data analyzed by methods developed by Boulton (1963), Stallman (1965), and Hurr (1966) indicate that the transmissivity of the aquifer in this area is about 40,000 square feet per day. An aquifer having an average width of 700 feet is capable of transmitting about 2 mgd (million gallons per day) of water with a hydraulic gradient of about 50 feet per mile. This is considerably less than the lowest daily mean flow of the Winooski River, estimated to be 147 mgd. If most of the pumpage is derived from infiltration through the streambed, the low flow of the river would fall below the recommended limit of 0.2 cfs per sq mi during drought. The river flows along the northwest edge of the esker at the test site and would be the major source of recharge to the underlying aquifer if withdrawal from wells was large. The pumping rate in this area is limited by the 1) low flow of the Winooski River and 2) recommended limitation on flow depletion rather than aquifer transmissivity.

Estimates of Available Water at Site 1

Practically all pumpage at this site would be derived from infiltration from the Winooski River because of small aquifer storage and scant recharge from precipitation. Calculations of discharge in the Winooski River at the test site are based on records at the Montpelier gaging station, 12.3 miles downstream. Approximately 160 square miles, or 40 percent of the drainage basin above the gaging station at Montpelier, lies above the East Montpelier test site. For the purpose of calculation, 40 percent of the water is assumed to originate above the test site. Reservoirs within the basin above the gage regulate some of the flow past the test site.

The Vermont Department of Water Resources' recommendation that 0.2 cfs per sq mi of drainage area be maintained as a base flow at all points on a stream requires a minimum flow of 32 cfs, or 20.8 mgd at the test site. Calculations based on streamflow at Montpelier indicate that the daily mean discharge past the test site is below 32 cfs on an average of 12 days per year but has been below this value for as many as 60 days in a single year (1964).

Potential pumping from this aquifer is, in part, related to streamflow adjacent to the site. If 1 mgd is pumped from wells and not returned to the river, the daily mean discharge of 32 cfs or less will occur on an average of 15 days per year. If 10 mgd is pumped from the aquifer, a daily mean flow of 32 cfs or less will occur on an average of 44 days per year. Any practical plan to pump water from this aquifer continuously would consider adequate compensating storage to maintain the minimum recommended low flow during drought.

Analysis of the water sample taken during the pumping test at site 1 is given in table 1. The manganese content is well above the limit of 0.05 ppm (parts per million) recommended by the U.S. Public Health Service (1962) for drinking water. However, continued pumping from this aquifer may result in a decrease in manganese as river water is induced into the aquifer; however, treatment to remove manganese probably will be required to meet Public Health standards for a public water supply.

Site 2 - East Montpelier, south from U.S. Route 2, across the Winooski River, on property owned by Mrs. R. Taylor and Mrs. F. Delair (fig 3). Approximately 0.8 mile east of East Montpelier Village. A seismic profile extending from U.S. Route 2 southward across the Winooski River indicated as much as 140 feet of unconsolidated material overlying bedrock. The maximum depth to bedrock occurs approximately 100 feet south of U.S. 2, but seismic velocities suggest that the material in this area may be too fine grained and impermeable to yield water easily. Near the river, the depth to bedrock is shallower; however, seismic velocities in the unconsolidated material in this area suggest that the subsurface material may be coarse grained and, therefore, suitable for future ground-water exploration.

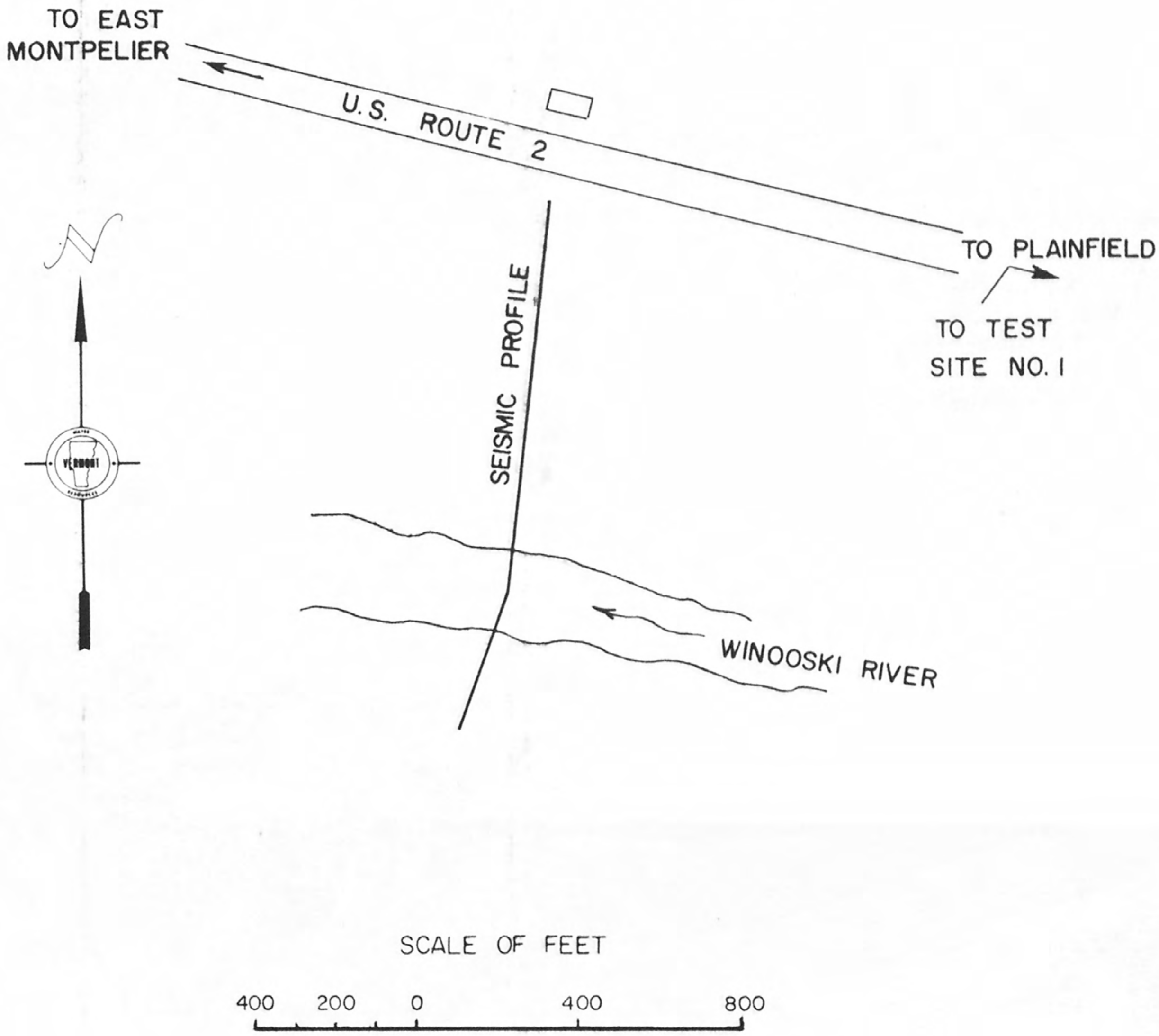

FIGURE 3 TEST SITE 2

Table 1.--Chemical analysis of ground water at site 1

Date: January 8, 1971 Previous pumpage: 2 days

(All values in milligrams per liter)

Calcium	64	Temperature, °F	46.0
Magnesium	6.4	Alkalinity as $CaCO_3$	179
Sodium	9.2	Color	6
Potassium	2.9	Dissolved solids at 180°C	232
Ammonia	.08	Dissolved solids, sum	229
Iron	.16	Hardness, Ca and Mg	186
Manganese	.43	Hardness, noncarbonate	7
Bicarbonate	218	Loss on ignition	26
Carbonate	0	Nitrate as N	.00
Sulfate	19	Nitrite as N	.01
Chloride	20	Nitrogen, NH_4 as N	.06
Fluoride	.0	pH	7.9
Nitrite	.05	Silica	.12
Nitrate	.00	Specific conductance	413

Site 3 - Middlesex, south from U.S. Route 2 to the Winooski River on property owned by DuBois Construction Company (fig. 4). Unconsolidated material overlying bedrock at this site is a maximum of 47 feet thick. A wash boring near the north bank of the Winooski River penetrated 28 feet of fine sand and clay overlying 12 feet of coarse sand and gravel. The lower material has sufficient permeability to produce water, but is too thin to be developed by high-capacity wells using standard well-construction methods. This area could be explored in the future for development as a well field.

Site 4 - Middlesex, near U.S. Route 2 underpass beneath Interstate 89 on property owned by the Town of Middlesex (see fig. 4). A single wash boring was driven in the delta of Sanny Brook. Thirty-one feet of sand and gravel were found underlying 56 feet of fine sand and clay. The sand and gravel yields little water.

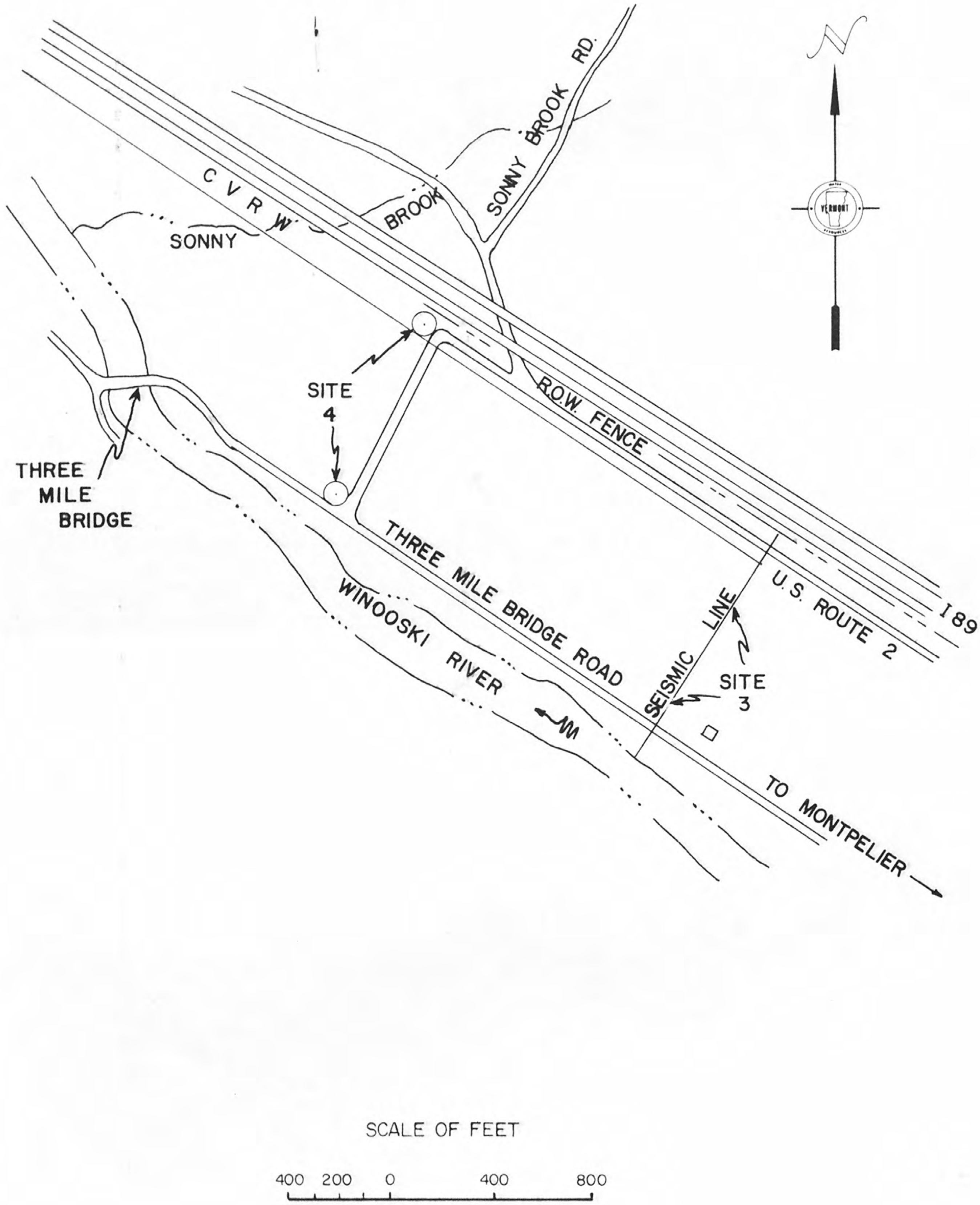

FIGURE 4 TEST SITES 3 and 4

Site 5 - Berlin, east from Vermont Route 12 across the Dog River and the Central Vermont Railroad on property owned by A.L. Granger (fig. 5). Rock walls confine the Dog River at this site to a narrow valley. Subsurface information from seismic profiling shows that, contrary to expectations, no deep buried channel exists below the present river level. The maximum depth to bedrock is 60 feet below the present channel of the river. A wash boring in the area of maximum depth penetrated only sand and silt that was too fine grained and impermeable to yield large supplies of water.

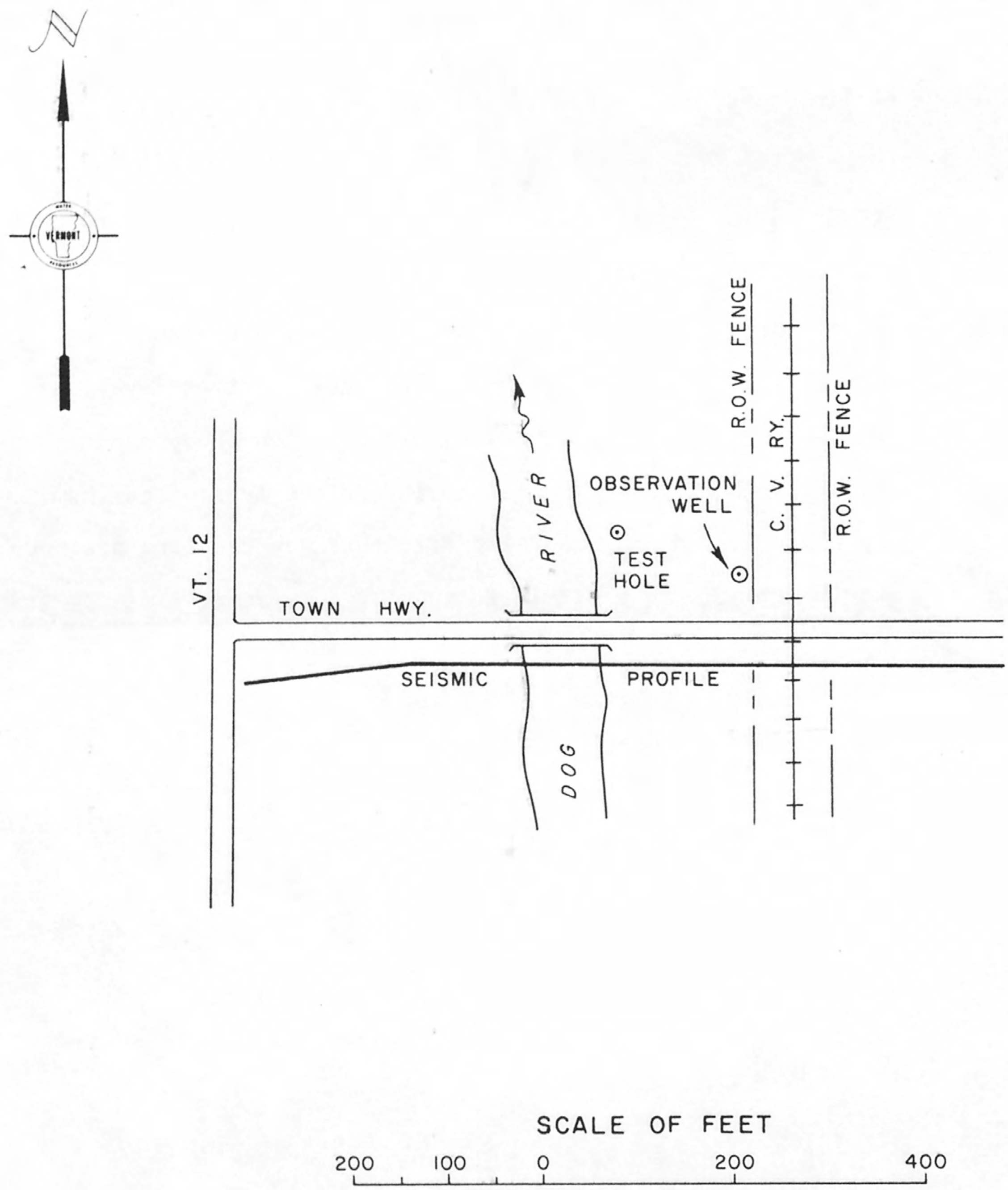

FIGURE 5 TEST SITE 5

Site 6 - Northfield, 0.4 mile south of Northfield Falls in a gravel pit owned by J. R. Covey, approximately 400 feet east of Vermont Route 12 (fig. 6). A rock ridge under and along the east edge of the highway separates the aquifer in a gravel-filled bedrock channel at the site from direct connection with the Dog River to the west. This ridge also would prevent movement of discharge from the Northfield Sewage Treatment Plant into the aquifer at the test site. Aquifer material beneath the site is recharged by precipitation and ground-water underflow from the east and south. Potential recharge may be available by induced infiltration from the Dog River 1,200 feet south of the test site. The actual cross-sectional area of the aquifer was not determined by seismic profiling because fuel-oil tanks are located within the pit, however, it is probably about 500 feet wide. Wash borings in the pit penetrated 49 feet of water-bearing sand and gravel having a static ground-water level 4 feet below land surface. An 8-inch test hole adjacent to the wash-bore holes penetrated 99 feet of sand and gravel. Casing was installed with screen between 75 and 95 feet below land surface, and, after 48 hours of pumping, the specific capacity was about 300 gallons per minute per foot of drawdown. Transmissivity of the aquifer estimated by extension of a method described by Hurr (1966) is approximately 65,000 square feet per day.

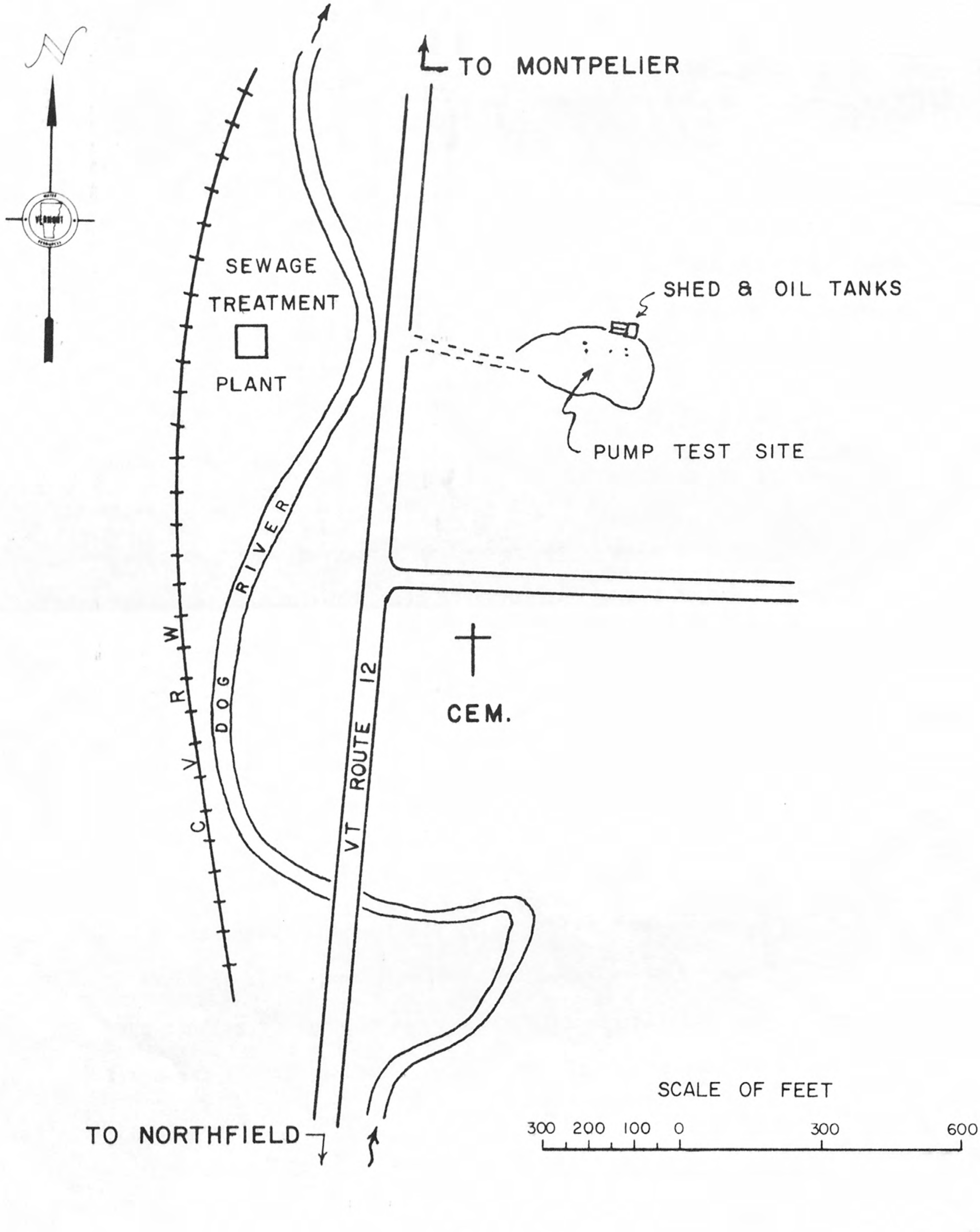

FIGURE 6 TEST SITE 6

Estimates of Available Water at Site 6

Calculations based on a transmissivity of 65,000 square feet per day indicate that the 500-foot cross section of aquifer is capable of transmitting about 2.5 mgd (million gallons per day) with a hydraulic gradient of about 50 feet per mile. Most of the recharge to the aquifer comes from precipitation on about 2 square miles of unconsolidated sediments east of the test site. It is estimated that half the yearly precipitation, or about 1 mgd, recharges the ground-water reservoir in sand and gravel.

The rate at which water would move from the Dog River into the underlying aquifer, once pumping lowers the water table beneath the river, depends on several factors: (1) the area of the streambed affected by well pumpage, (2) the vertical hydraulic gradient across the streambed, (3) the vertical permeability of the streambed, and (4) the temperature of the stream water. Estimates of average vertical streambed infiltration made by Rosenshein and others (1968) in Rhode Island, Randall and others (1966) in Connecticut, and Norris and Fidler (1969) in Ohio indicated that the average streambed infiltration rate ranged from about 17 gallons per day per square foot to 50 gallons per day per square foot with 1 foot of vertical head. No testing was done on the Dog River to determine streambed infiltration rates, but, based on the findings of the above studies, a value of 25 gallons per day per square foot seems to be reasonable.

Infiltration from the Dog River would probably occur south of the test site between the well and the river along a 500-foot reach of the stream that has an average width of 25 feet during low flow. The minimum area of infiltration, therefore, is about 12,500 square feet. At the estimated rate of infiltration of 25 gpd per sq ft, approximately 300,000 gpd, or 0.5 cfs, may be induced into the aquifer from the Dog River during low flow. This volume is less than 7 percent of the lowest daily flow of record at the Northfield gage.

Average annual discharge of the Dog River adjacent to test site 6 is about 92 cfs from a drainage area of 61 square miles. Low flow based on State recommendations should not be less than 12 cfs. Estimates of low flow based on data for the Northfield gaging station indicate that streamflow adjacent to the test site is 12 cfs or less on an average of 40 days per year. Infiltration of streamflow of 300,000 gpd caused by pumping would reduce streamflow at the site below the recommended limit for periods longer than 40 days per year.

In summary, a well or group of properly constructed wells favorably located to intercept most recharge, could dependably yield about 1 mgd with little streamflow depletion resulting from infiltration.

An analysis of water collected from the test well at site 6 is given in table 2. All chemical constituents were found to be well below limits recommended by the Public Health Service for a public water supply and, therefore, the water should be usable without treatment other than chlorination.

Site 7 - Northfield, east side of Dog River on property owned by Norwich University (fig. 7). Three wash borings were driven between the campus of Norwich University and the Dog River. Depth to bedrock ranged from 24 feet to 65 feet below land surface. Subsurface material ranged from fine sand and clay to coarse gravel mixed with silt. Gravel layers below a depth of 35 feet were tested by pumping, but they contained sufficient silt to make the permability low. Shallow gravel adjacent to the Dog River, however, may be a potential aquifer that can be developed by infiltration galleries, groups of well points, or collector wells.

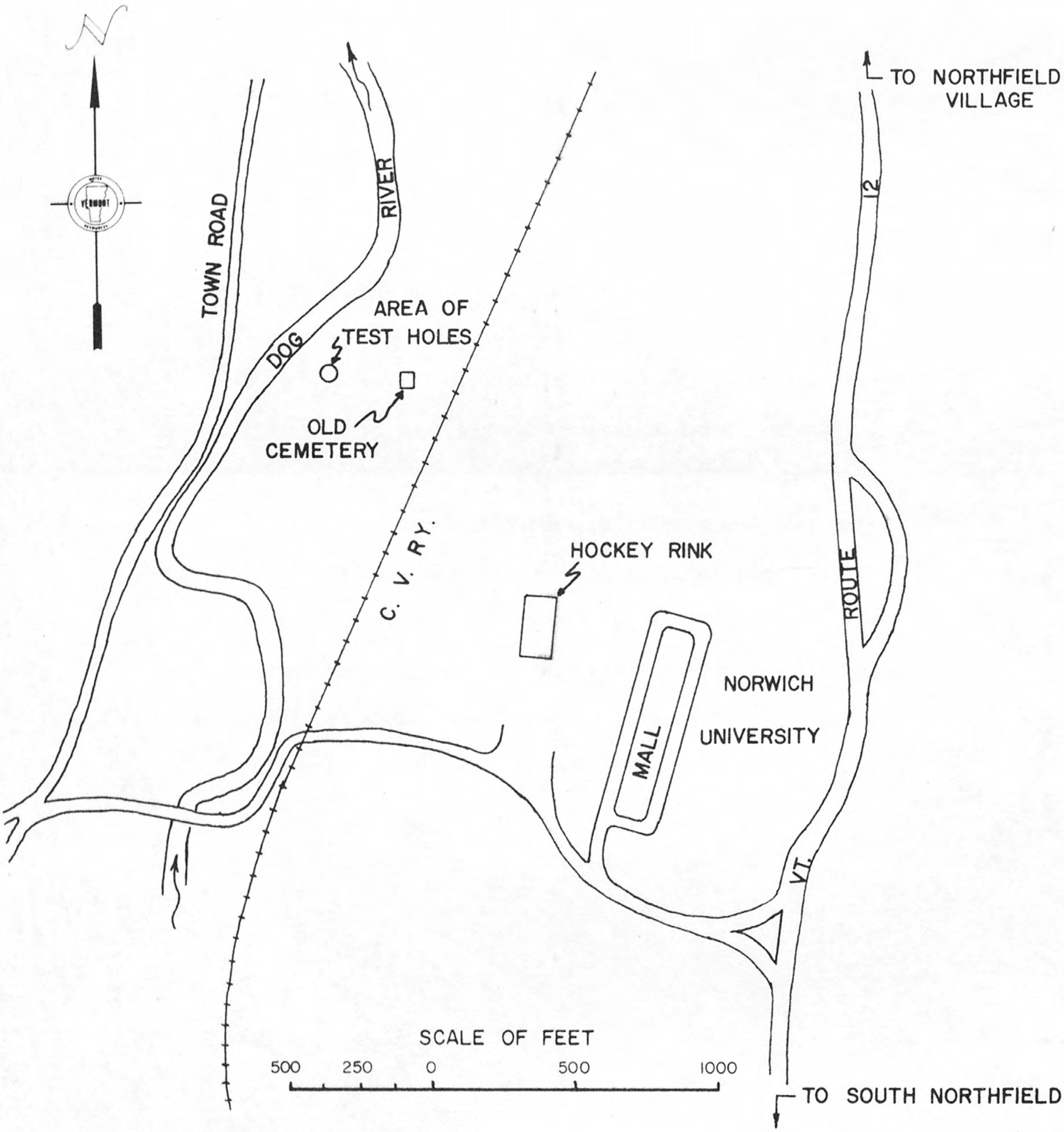

FIGURE 7 TEST SITE 7

Table 2.--Chemical analysis of ground water at site 6

Date: March 18, 1971 Previous pumpage: 2 days

(All values in milligrams per liter)

Calcium	22	Temperature, °F	45.5
Magnesium	3.9	Alkalinity as $CaCO_3$	43
Sodium	7.8	Color	2
Potassium	.9	Dissolved solids at 180°C	140
Ammonia	.02	Dissolved solids, sum	104
Iron	.10	Hardness, Ca and Mg	71
Manganese	.00	Hardness, noncarbonate	28
Bicarbonate	53	Loss on ignition	38
Carbonate	0	Nitrate as N	1.0
Sulfate	14	Nitrite as N	.11
Chloride	18	Nitrogen, NH_4 as N	.02
Fluoride	.0	pH	6.8
Nitrite	.37	Silica	6.4
Nitrate	4.6	Specific conductance	191

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GROUND-WATER RESOURCES

OF THE

BARRE-MONTPELIER AREA, VERMONT

BY

1931-

ARTHUR L. HODGES, JR., DAVID BUTTERFIELD, AND JAMES W. ASHLEY

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
STATE OF VERMONT
AGENCY OF ENVIRONMENTAL CONSERVATION
DEPARTMENT OF WATER RESOURCES

1976

INTRODUCTION

A study of the ground-water resources of the Barre-Montpelier area was begun in 1968 by the U. S. Geological Survey in cooperation with the Vermont Department of Water Resources. The results of the study are presented in this report.

Ground water in the Barre-Montpelier area occurs in bedrock, and in overlying unconsolidated deposits of glacial origin. Zones within the bedrock or the overlying unconsolidated deposits that easily yield water to wells are called "aquifers." Bedrock in the area is composed of a series of shallow to steeply dipping metamorphic rocks that have been intruded by several bodies of granite. These rock units have been mapped and described by Cady (1956), Murthy (1957), Konig (1961), and Doll (1961). The rock units are composed of interlocking mineral grains that have no openings between them that contain water. Virtually all water obtained from rock wells in the report area is derived from fractures (joints or faults) in the rock. The occurrence of water in bedrock is discussed on Plate 1.

Unconsolidated deposits overlying bedrock are the result of several periods of glaciation during Pleistocene time. Moving ice removed soil and rounded and shaped the bedrock surface as it overspread the area. Some of the material removed by the ice was later deposited as an unsorted mixture called till that contains material ranging in size from clay particles to boulders. As ice masses began to waste away, meltwater streams carried debris from the ice and exposed hillsides and deposited it as sorted and layered beds of sand and gravel. When these streams entered glacial lakes, silt and clay settled from the water, filling some of the lakes completely. Ground-water occurs between the grains of unconsolidated material below the water table. The rate at which water can be removed from these deposits and utilized, however, is dependent largely upon the size of the openings between the individual grains. Thus, water can be removed from a saturated sand or gravel much more rapidly than from a saturated clay. The occurrence of water in the unconsolidated deposits is discussed on Plate 2. Results of aquifer tests of the unconsolidated deposits are given in an accompanying report, "Ground-Water Availability in the Barre-Montpelier Area" (Hodges and Butterfield, 1972).

Basic data used in compiling this report are given on Plate 3.

Well identification numbers used in this report are composed of a two-letter town or city code, the letter **A**, **W** or **X** and a sequential number. The town and city codes are shown on the data point location map (figure 1, plate 3).

The authors of this report appreciate the courtesy that was extended to them by numerous individuals and agencies during collection of data. The Department of Agriculture, Farmers Home Administration, granted funds that made aquifer testing possible. Many landowners granted permission for various tests on their property, and the Vermont Department of Highways provided access to data in their files relating to the subsurface. We thank those water-well drillers that provided information through their well-completion reports.

The stratigraphic nomenclature used in this report is that of the Vermont Geological Survey and does not necessarily follow the usage of the U.S. Geological Survey.

The following ground-water reports are available at the Vermont Department of Water Resources, State Office Bldg., Montpelier, Vermont 05602.

GROUND WATER FAVORABILITY MAP of the BATTEN KILL, WALLOOMSAC RIVER AND HOOSIC RIVER BASINS; A. L. Hodges, Jr., 1966

GROUND WATER FAVORABILITY MAP of the OTTER CREEK BASIN, VERMONT; A. L. Hodges, Jr., 1967

GROUND WATER FAVORABILITY MAP of the WINOOSKI RIVER BASIN, VERMONT; A. L. Hodges, Jr. 1967

GROUND WATER FAVORABILITY MAP of the LAMOILLE RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1967

GROUND WATER FAVORABILITY MAP of the MISSISSQUOI RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1967

GROUND WATER FAVORABILITY MAP of the LAKE MEMPHREMAGOG BASIN, VERMONT; A. L. Hodges, Jr., 1967

GROUND WATER FAVORABILITY MAP of the NULHEGAN-PASSUMPSIC RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1967

GROUND WATER FAVORABILITY MAP of the WELLS-OMPOMPANOOSUC RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1968

GROUND WATER FAVORABILITY MAP of the WHITE RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1968

GROUND WATER FAVORABILITY MAP of the OTTAUQUECHEE-SAXTON RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1968

GROUND WATER FAVORABILITY MAP of the WEST-DEERFIELD RIVER BASIN, VERMONT; A. L. Hodges, Jr., 1968

GROUND WATER RESOURCES of the BARRE-MONTPELIER AREA, VERMONT; A. L. Hodges, Jr., David Butterfield and J. W. Ashley, 1976