In reference to report:
Mack, T.J., 2009, Assessment of ground-water resources in the Seacoast region of New Hampshire: U.S. Geological Survey Scientific Investigations Report 2008–5222, 188 p., available online at http://pubs.usgs.gov/sir/2008/5222.

Appendix 2. Bedrock-Well Yields

Figure

Tables

Appendix 2. Bedrock-Well Yields

Yields reported by drillers and discussed in this report generally were short-term (30-minute) air-lift yields and were considered approximate measures of sustained well yields. Examination of drillers' reported yields and aquifer-test yields for other wells in New Hampshire where more rigorous yield tests were required (Brandon Kernen, New Hampshire Department of Environmental Services, written commun., 2005) indicated that drillers' yields were similar to yields determined by aquifer tests. For example, about 40 percent of driller-reported and aquifer-test yields in the study area differed by less than 10 percent, and 67 percent of the yields differed by less than 20 gal/min. The statistical distribution of bedrock-well yields in the project area was skewed towards low yields (less than 10 gal/min), whereas well depths have a more normal statistical distribution than yields. Areas of moderate and high yields (10 and 40 gal/min) were fairly uniformly distributed throughout the study area. A variogram analysis of yields, however, indicated that yields were more similar in a northeast direction, the direction of the regional bedrock structure.

Statewide (Moore and others, 2002), the average bedrock well yield is approximately 6 gal/min, whereas the average yield of bedrock wells in the study area is 22 gal/min. Table 2–1 shows bedrock well-yield and depth statistics by bedrock formation for the study area. The means and standard deviations of yield by formation, as determined by Moore and others (2002) with an older, smaller data set, are listed in table 2–1 for comparison. Some formations—for example, the Breakfast Hill Granite, Rye, and Kittery Formations, and the Newburyport Complex—are entirely in the model area; and, therefore, the differences in the number of wells represent the addition of wells. The regional variations in well yields associated with each formation were similar to the variations in the data used by Moore and others (2002). For example, the Rye Complex previously had 29 wells with an approximate mean yield and standard deviation of 39 and 63 gal/min, respectively, and now has 239 wells with an approximate mean yield and standard deviation of 34 and 42 gal/min (table 2–2). Therefore, the yield probability relations and general trends found by Moore and others (2002) hold true for the current study. The high standard deviations, relative to the mean values reflect the fact that the yield distributions are skewed toward lower values.

Nonzero well yields less than or equal to 40 gal/min in central New Hampshire (Drew and others, 2001) and in a similar crystalline-bedrock setting in Virginia (Sutphin and others, 2000) have also been found to have directional yield characteristics related to the rock structure. Directional yield characteristics were assessed by using ArcView[1] variographic analysis (Environmental Science Research Institute). Low-yielding wells were more likely to be spatially correlated because the regional hydraulic characteristics of the bedrock aquifer were controlled, or limited, by the smaller fractures of the bulk rock. For example, a fracture zone may locally provide a zone of increased hydraulic conductivity; however, unless wells are tested within a limited distance of this same fracture zone, the hydraulic conductivity of the bulk rock will provide the hydraulic connection in the region and be the principal factor determining the well yields. The hydraulic connection of the bulk rock also may be termed the "connectivity." Variographic analysis of yields greater than zero and less than 60 gal/min indicate a north-to-northeast-trending spatial continuity (table 2–2). Because bedrock wells yields in the Seacoast study area were higher than those analyzed in similar variographic investigations (Drew and others, 2001; Sutphin and others, 2000) higher well yields were included in this analysis than in other investigations. The northeast trend is likely to be related to the regional bedrock structure and has also been observed in fractures oriented along bedding planes (Escamilla-Casas, 2003; Fargo and Bothner, 1995; Novotny, 1969), local borehole investigations (Mack and Degnan, 2003; Mack and others, 1998; and Johnson and others, 1999), fracture-correlated lineaments (Degnan and Clark, 2002), and in regional bedrock-yield probabilities (Moore and others, 2002).

[1] Use of commercial software name for informational purposes.

Table 2–1. Bedrock well yields and depth characteristics for geologic units in the Seacoast model area and in southeastern New Hampshire.

[Geologic unit and geologic code shown on figure 2–1: Lyons and others (1997); gal/min, gallons per minute; ft, feet; —, not applicable or not calculated]

Geologic unit	Dominant lithology	Geo-logic code	Model code	Seacoast model area[1]					Southeastern New Hampshire[2]		
				Number of wells	Yield (gal/min)		Depth (ft)		Yield (gal/min)		
					Mean/median	Standard deviation	Mean/median	Standard deviation	Number of wells	Mean	Standard deviation
Exeter Diorite	Diorite	DE9	Rx4	78	19/11	22	281/250	145	82	15	22
Breakfast Hill granite	Granitic gneiss or migmatite	OZrb	Rx1	88	26/20	28	295/240	186	23	18	28
Rye Complex	Schist and gneiss	OZrz	Rx1	239	34/20	42	263/240	134	29	39	63
Newburyport Complex[3]	Porphoritic granite	SN1x	Rx4	50	24/17	24	276/242	138	2	12	12
Newburyport Complex	Tonalite and granodiorite	SN2-3a	Rx4	—	—	—	—	—	3	49	61
Berwick Formation	Schist	SOb	Rx4	79	14/8	16	322/300	139	1,595	16	27
Eliot Formation	Phyllite	SOe	Rx3	875	20/12	22	265/225	137	292	16	20
Kittery Formation	Metasandstone	SOk	Rx2	824	22/15	24	266/240	126	169	27	56
All	—	—	—	2,237	22/15	26	269/240	136	—	—	—

[1] Based on extent of the geologic unit in the model area shown in figure 2–1 and wells in the New Hampshire Geological Survey database as of March 2006.

[2] Based on extent of the geologic unit in southeastern New Hampshire as used by Moore and others, 2002.

[3] Statistics in Seacoast model area shown for combined Newburyport Complexes.

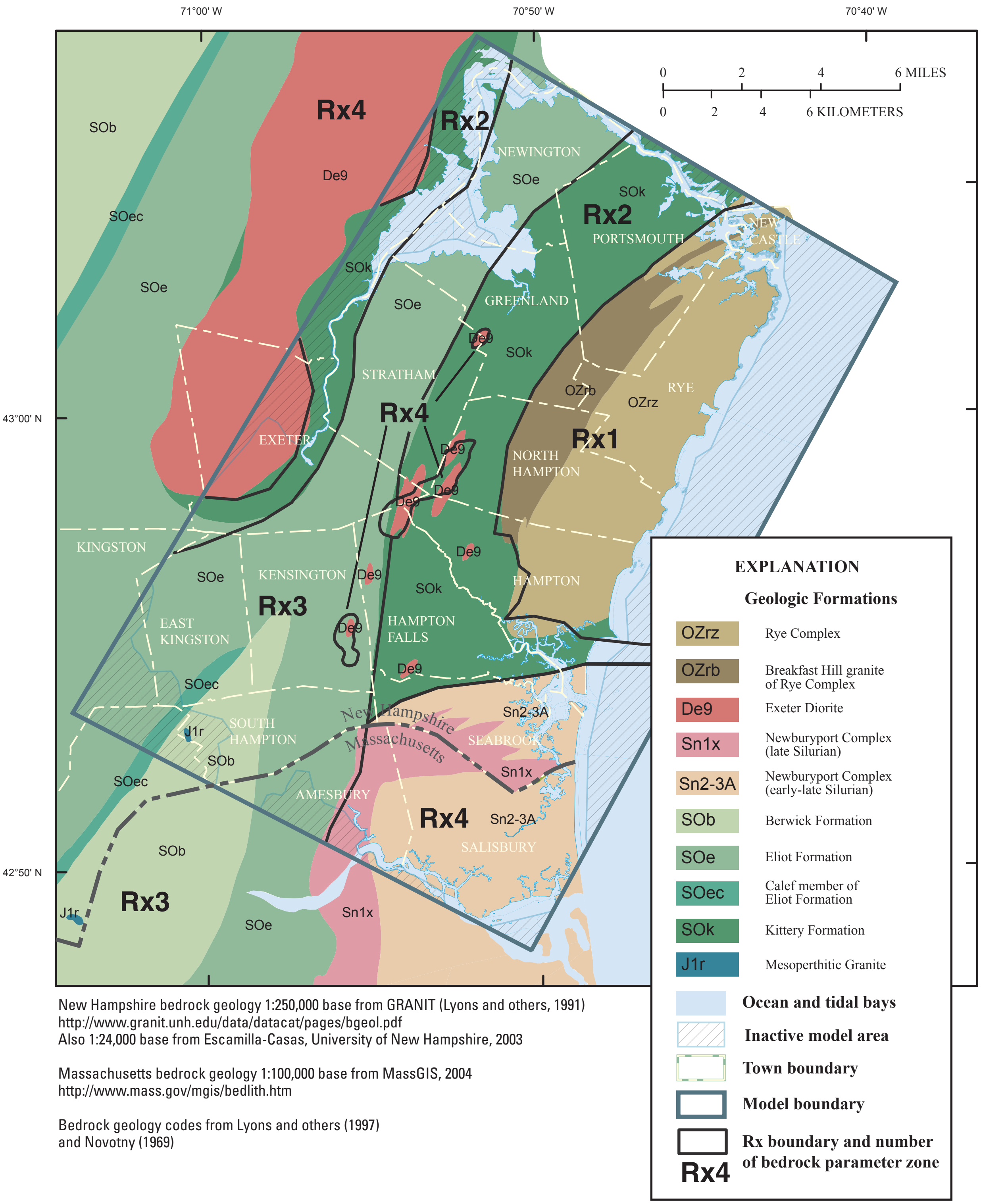
Table 2–2. Bedrock well yield variography and geologic units within the Seacoast model area, southeastern New Hampshire.

[Formation and code from Lyons and others (1997); Variography (anisotropy) calculated for well yields less than 60 gallons per minute[1] by using ArcView (Environmental Systems Research Institute)[2]; gal/min, gallons per minute[1]; Deg.TN, degrees from true north; —, not available]

Geologic unit	Dominant lithology	Geologic code	Number of wells	Yield trend orientation and range of trend line, indicates anisotropy		Notes
				Direction Deg. TN	Approximate well-yield range (gal/min)	
All	Varies		1,571	—	10–20	Higher yields in middle of study area and increasing to east.
Newburyport Complex	Granite, tonalite, and granodiorite	SN1x, SN2–3a	34	—	—	Too few points to assess trends; however, may be higher at contacts.
Breakfast Hill granite	Granitic gneiss or migmatite	OZrb	74	34	10–30	Greater yields towards center of unit.
Rye Complex	Schist and gneiss	OZrz	204	20	10–30	Greater yields towards center of complex.
Kittery Formation, east	Metasandstone	SOk	623	60	15–20	Little trend.
Kittery Formation, west	Metasandstone	SOk	58	24	28–38	Greater yields towards contacts.
Eliot Formation	Phyllite	SOe	408	29	10–20	Little trend, slightly greater yields towards center of formation.
Berwick Formation	Schist	SOb, SOeb	73	58	15–30	Strongly convex, greater yields in center and increasing to southwest.
Exeter Diorite	Diorite	De9	55	67	18–28	

[1] Based on extent of geologic unit in the model area shown in figure 2–1 and wells in the New Hampshire Geological Survey database as of March 2006.

[2] Use of commercial software name for informational purposes.



New Hampshire bedrock geology 1:250,000 base from GRANIT (Lyons and others, 1991)
http://www.granit.unh.edu/data/datacat/pages/bgeol.pdf
Also 1:24,000 base from Escamilla-Casas, University of New Hampshire, 2003

Massachusetts bedrock geology 1:100,000 base from MassGIS, 2004
http://www.mass.gov/mgis/bedlith.htm

Bedrock geology codes from Lyons and others (1997)
and Novotny (1969)

Figure 2–1. Dominant bedrock formations in the Seacoast area and bedrock parameter zones used in the Seacoast model, southeastern New Hampshire. (This figure is the same as figure 4 on page 7 in the report.)

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