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Appendix 3. Tidal Water-Level Responses in Wells

Figures

Appendix 3. Tidal Water-Level Responses in Wells

Water levels in the bedrock aquifer show a confined aquifer response to Earth tides and barometric pressure changes. Tidal responses in Seacoast bedrock wells were examined to assess their use in quantifying aquifer properties and to assess hydraulic connections between the freshwater aquifer and the ocean and estuaries. Figure 3–1 illustrates water-level fluctuations in three wells in the bedrock aquifer typical of an earth-tide response in the region. Measured fluctuations were about 0.2 to 0.4 ft and 0.1 to 0.2 ft, respectively, for wells GTW-141 and HEW-44 (figs. 3–1A and 3–2). A similar response has been observed at bedrock wells considerably inland where there is no connection to ocean tidal fluctuations (ground-water level hydrographs can be accessed at http://waterdata.usgs.gov). For example, hydrographs for PBW-148 (about 35 mi inland), and ME-ANW-1135 (about 20 mi inland) show typical earth-tide ranges of 0.05 to 0.1 ft and 0.2 to 0.4 ft, respectively. In areas where there is no hydraulic connection to tidal waters, the earth-tide effect on bedrock-aquifer ground-water levels is opposite of the tidal effect on the oceans. As gravitational forces from planets and the moon and sun pull at the surface of the earth, surface gravity is less, fractures in the rock are dilated, and ground water fills the fractures, causing the bedrock water level to drop. When the gravitational force is included, gravitational attraction is higher, and the fractures close forcing water out of the fractures and raising the water level. The magnitude of the earth-tide response differs with bedrock-aquifer transmissivity and storativity (or specific storage times thickness) and with tidal gravity (Merritt, 2004; Bredehoft, 1967; Hsieh and others, 1987, 1988). It is possible to estimate the hydraulic diffusivity of an aquifer (the hydraulic conductivity divided by the specific storage) from measurements of earth-tide water-level fluctuations and the magnitude and timing of gravitational forces, which can be calculated for any location (Hsieh and others, 1987, 1988; Merritt, 2004). The approximate yield of bedrock wells in the region is generally determined during drilling and is more accurate than could be estimated by gravitational methods. Specific storage and porosity, which generally require aquifer or borehole testing, however, can be estimated by an analysis of earth tides by the methods outlined by Merritt (2004) and Sheets and Darner (U.S. Geological Survey, written commun., 2006). Porosity is related to specific storage using barometric efficiency (from analysis of earth tides and the compressibility and density of water (Merritt, 2004). Porosity and specific storage were calculated for wells GTW-141, HEW-44, and PBW-148 (Sheets and Darner, U.S. Geological Survey, written commun., 2006). A porosity of 0.02 and specific storages of 1.5×10^{-7}, 2.4×10^{-7}, and 4.0×10^{-7}, respectively, were estimated for the aquifers in which the three wells are completed. Approximately 86 percent of the variance in well water levels, detrended for barometric influence, was explained by earth-tide effects.

The tidal water levels in wells were qualitatively assessed for hydraulic characteristics and to assess whether ocean-tides propagate into the Seacoast fractured bedrock aquifer. Earth-tide effects on bedrock water levels in the study area can be qualitatively assessed by comparison to water levels in bedrock well PBW-148, 35 mi west of the study area. Tidal responses occurred at the same time throughout the area. The gravitational forces caused by the moon and sun, because of their magnitudes and distances from Earth, can be considered to be equal and instantaneous (no lag) throughout southeastern New Hampshire and Maine. For example, comparison of water levels at PBW-148 and ME-ANW-1135 (hydrographs accessible at waterdata.usgs.gov) shows that the timing of the earth-tide peaks in water levels is identical.

Water-level records for bedrock monitoring well GTW-141 (fig. 3–1) were not found to have a measurable connection with ocean tides. This well is less than 50 ft from a section of the Winnicut River on the south side of Great Bay with a mean tidal range of about 7 ft. The tide at the Squamscott River railroad bridge, about 3.5 mi to the west in Great Bay and at a distance about equal to that of the well from the ocean, has a phase lag of 2 hours after the high and low ocean tides. Squamscott River has a mean tidal range of 7 ft, whereas the ocean has a mean range of about 8 ft. On September 29, 2004, the water level in the well peaked at 07:00 and 18:00 hours, at the same time as water-level peaks in other bedrock observation wells in the area, while the bay tide peaked at 01:18 and 13:40 (EST). The ocean tide peaks were at 23:13 (previous night) and 11:34, or about 7 hours offset from the peak water level in the bedrock. Water levels completed in bedrock wells with very low permeability showed no earth-tide response (Pease monitoring well W611, not shown in fig. 3–1; Montgomery, Watson, Harza, 2002). Bedrock aquifers with low hydraulic conductivity have few fractures to expand and contract and few connections for water to move between fractures. In contrast, water levels monitored at a high-yielding well, for example monitoring well RYW-49 (fig. 3–2), showed little tidal response (0.1–0.2 ft) because the bedrock aquifer at that location is essentially unconfined and responds differently to pressure loading.

Water-level records for two wells immediately adjacent to tidal water bodies in Hampton, N.H., were examined because the wells were believed to be mixed with or include ocean water. The wells were assumed to be hydraulically connected to tidal water bodies because the daily water-level fluctuation observed in the wells did not follow the earth-tide pattern described above. For example, figure 3–1B shows the resulting water-level fluctuation in a well (HEW-153) that is affected by both earth and ocean tides. The water-level responses in the wells were influenced by conflicting earth and ocean tides; the result for each well was a single daily water-level peak that was more closely aligned with the larger ocean tide. It is interesting to note that although well GTW-141 also is very close to a saltwater body (Great Bay, fig. 3–2), the well is not contaminated by chloride. The hydraulic head in this inactive well is above sea level because of the regional ground-water-flow system; if the well were in use, the head would be lower.

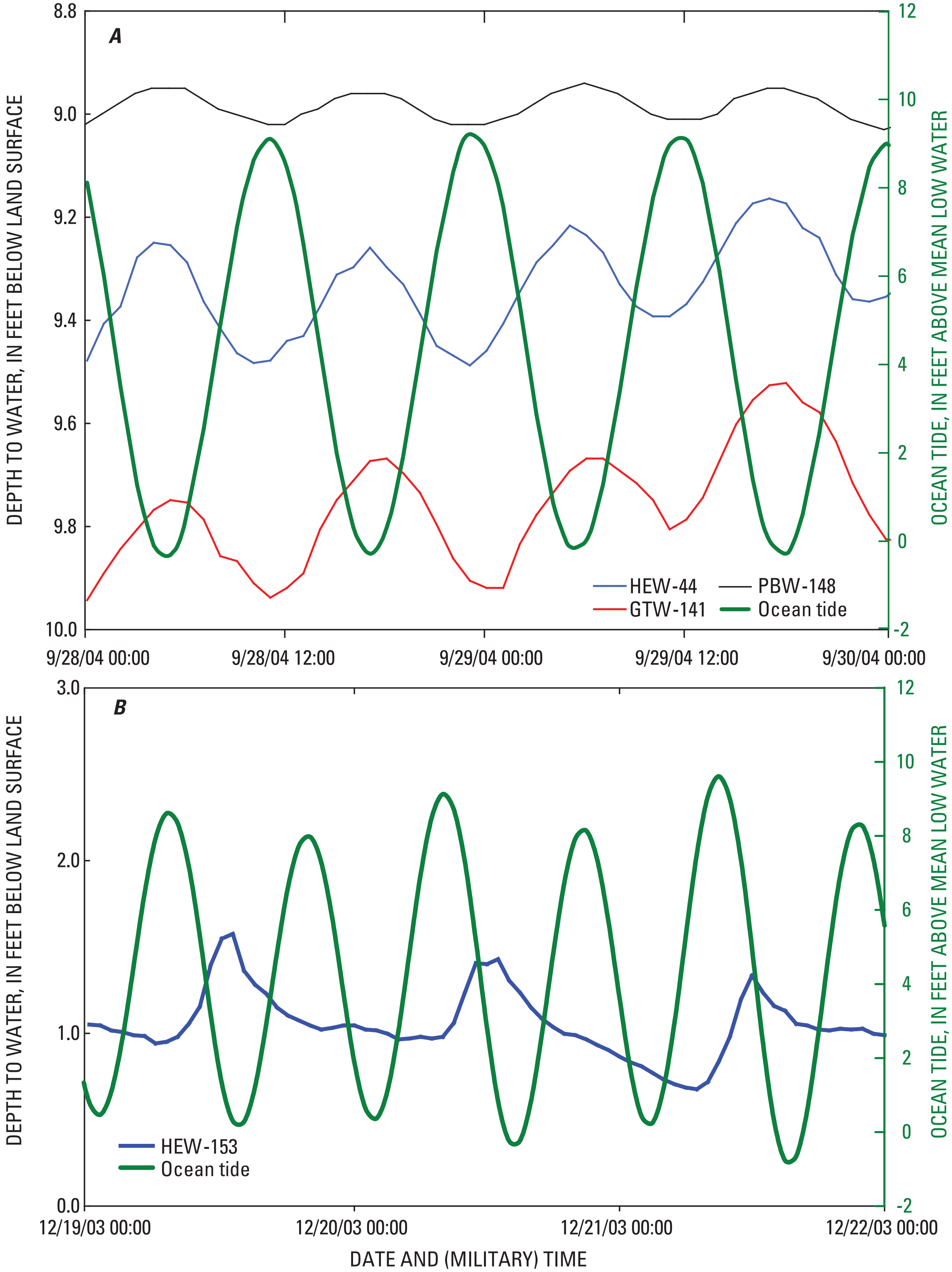

Figure 3–1. Earth-tide water-level responses and ocean tides at *(A)* observation wells GTW-141, HEW-44, PBW-148, unaffected by ocean tides, and at *(B)* observation well HEW-153, affected by ocean tides, southeastern New Hampshire. (Location of wells shown on figure 3–2. Well PBW-148 is outside the study area and not shown on any figure.)

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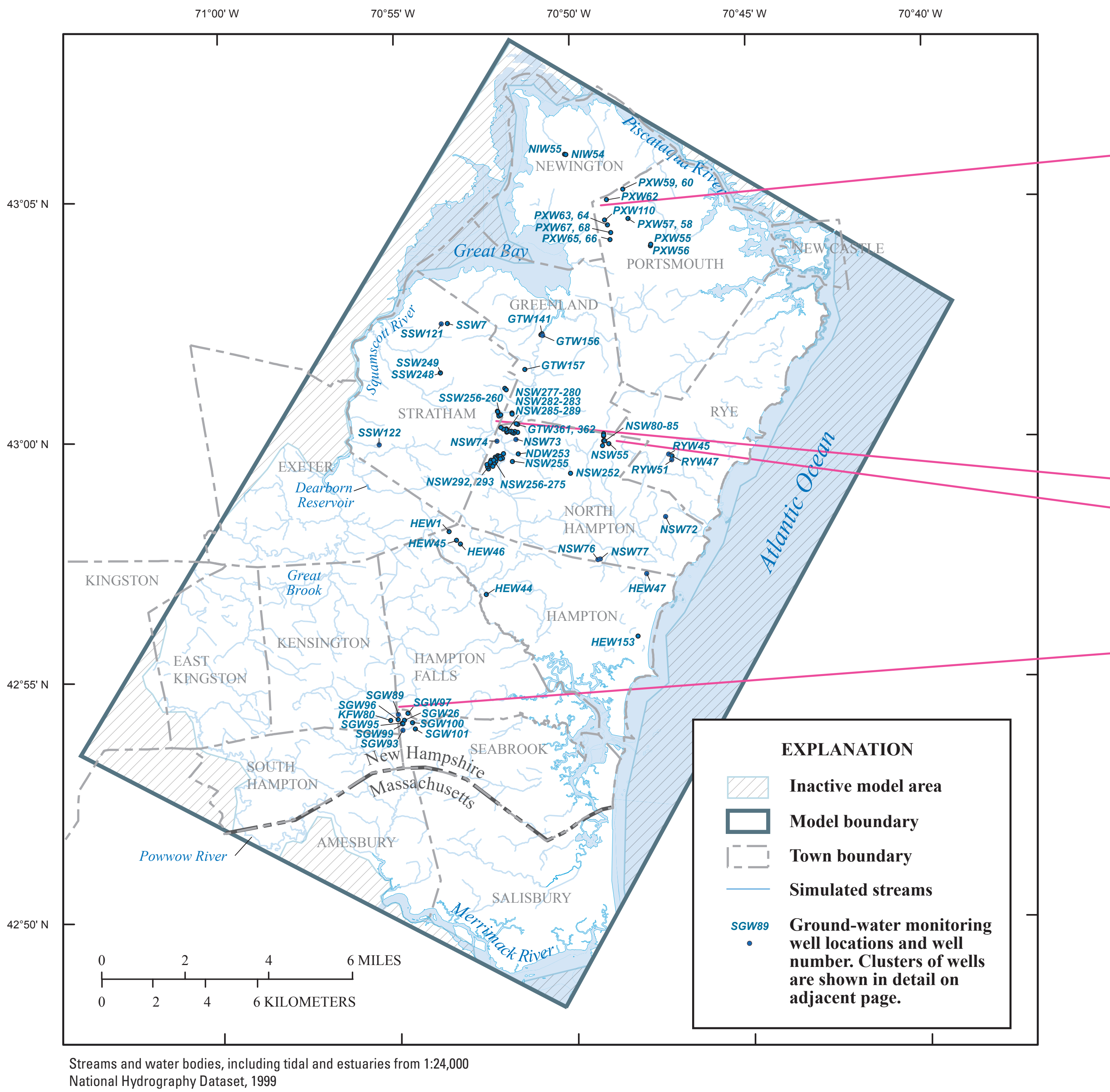
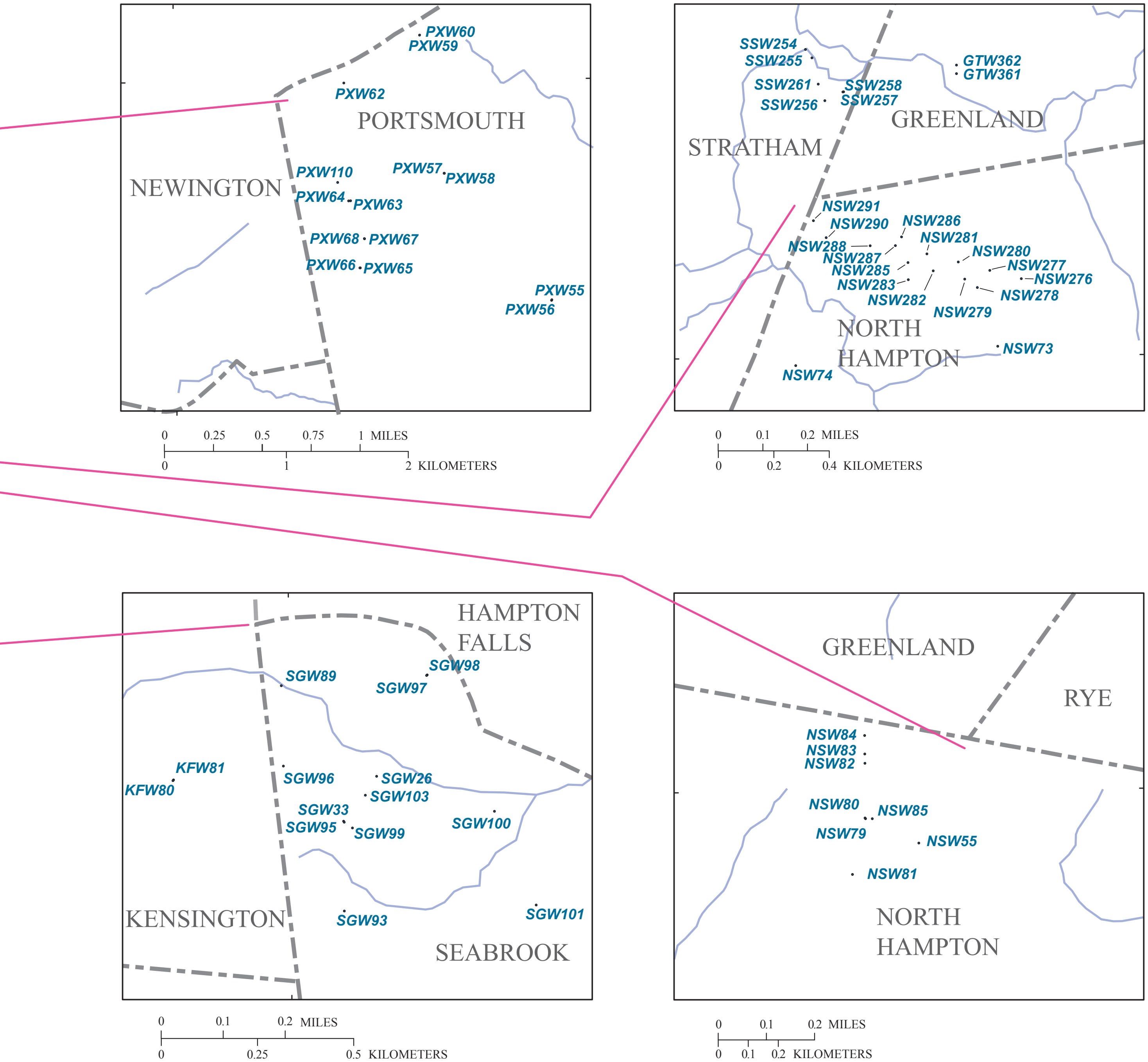


Figure 3–2. *(A)* Ground-water monitoring wells in the study area. (This figure is the same as figure 7 on page 16–17 in the report.)


PXW60
PXW59
PXW62
PORTSMOUTH
NEWINGTON
PXW110
PXW57
PXW58
PXW64
PXW63
PXW68
PXW67
PXW66
PXW65
PXW55
PXW56
0 0.25 0.5 0.75 1 MILES
0 1 2 KILOMETERS
SSW254
SSW255
GTW362
GTW361
SSW261
SSW258
SSW256
SSW257
GREENLAND
STRATHAM
NSW291
NSW290
NSW286
NSW281
NSW288
NSW287
NSW280
NSW285
NSW277
NSW276
NSW283
NSW278
NSW282
NSW279
NORTH
HAMPTON
NSW73
NSW74
0 0.1 0.2 MILES
0 0.2 0.4 KILOMETERS
HAMPTON
FALLS
SGW98
SGW89
SGW97
KFW81
KFW80
SGW96
SGW26
SGW103
SGW33
SGW95
SGW99
SGW100
KENSINGTON
SGW93
SGW101
SEABROOK
0 0.1 0.2 MILES
0 0.25 0.5 KILOMETERS
GREENLAND
RYE
NSW84
NSW83
NSW82
NSW80
NSW85
NSW79
NSW55
NSW81
NORTH
HAMPTON
0 0.1 0.2 MILES
0 0.1 0.2 KILOMETERS

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