

ESTIMATING HIGHEST GROUND-WATER LEVELS FOR CONSTRUCTION AND LAND USE PLANNING—A CAPE COD, MASSACHUSETTS, EXAMPLE

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METRIC CONVERSION FACTORS

The following factors may be used to convert inch-pounds
to the International System of Units (SI).

Multiply	By	To obtain
inch (in)	2.540 0.254	centimeter (cm) decimeter (dm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

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ABSTRACT

High ground-water level is one major cause of septic-system failures, wet basements, and other serious problems for suburban and rural residents. A technique for estimating the level to which ground water can rise as a consequence of weather and seasonal factors has been developed to assist the homebuilding industry and health officials who design, construct, or regulate septic systems. Water-level records from about 160 sites were used to make four maps of annual water-level ranges: 0-2 feet, 2-3 feet, 3-4 feet, 4-5 feet, and 5-6 feet. Nine observation wells with 16 or more years of record were used to index water-level fluctuations throughout Cape Cod. To estimate high water levels, measurements of the current depth to water at test sites are cross referenced with current depth to water in the index wells.

This report uses septic-system regulations on Cape Cod, Massachusetts, as an example. The technique can also be used at potential building construction sites and other places where estimates of highest ground-water levels are needed.

The technique assumes good correlations between water-level fluctuations at septic-system sites and the index wells. Eighty-seven percent of the correlation coefficients determined from correlating water-level fluctuations from 146 sites with water-level fluctuations in the index wells were greater than 0.8.

INTRODUCTION

Problems with High Ground-Water Levels

High ground-water levels are a major cause of septic-system failures, wet basements, and other problems for suburban and rural residents. For example, unexpectedly high ground-water levels may flood septic system, causing sewage to back up in the system, break out at land surface, produce obnoxious odors, and devalue property (fig. 1). Persons who come in contact with untreated sewage may be exposed to bacterial and viral diseases such as infectious hepatitis, dysentery, and diarrhea.

This report presents an estimating technique that could be employed, with certain adaptations, almost anywhere that high ground-water levels in sedimentary deposits may present construction planning problems such as design and safe use of septic tank drain fields, and design of foundations, basements, and roadways. Conditions leading to these problems could be anticipated during design phases of construction. The guide can be used during any season of the year, thus eliminating the need to restrict water-level measurements to the spring. It can thereby relieve builders, construction engineers, and health officials of seasonal restric-

tions on site testing in many situations. Transfer of the technique to other areas of relatively uniform climate, weather, and hydrologic conditions may only require analysis of available data from geologic maps and observation well networks.

Although the report uses septic-system design as an example, the technique also applies to potential building sites and other places where estimates of highest ground-water levels are needed. To avoid septic-system failure caused by high ground-water levels, the U.S. Public Health Service (1969) and the Massachusetts Department of Environmental Quality Engineering (1977) have recommended that the bottoms of domestic septic systems be at least 4 feet above the maximum elevation of the water table. The aerated soil between the bottom of the septic system and the water table acts as a safety zone against flooding and also provides physical, chemical, and microbial treatment of the sewage to convert the constituents into less noxious forms. Accurate estimates of high ground-water levels are, therefore, necessary for the design of effective septic systems.

Ground-Water Levels Vary with Time and Location

Ground-water levels can fluctuate several feet in response to weather and the changing seasons. A single water-level measurement, while easily obtained, will rarely represent the extreme ground-water levels. During the warm months of summer when evaporation and transpiration rates are high, water levels decline, reaching their lowest levels in late fall (fig. 2). During the winter months, water levels rise and commonly reach their peaks following the melting of snow and ice in March and April. Recognizing this seasonal variation in water levels, some public health agencies have decided to only accept water levels measured during winter and spring for septic-system permit applications.

Other factors cause fluctuations in water level as well. A drought, such as that experienced during the mid-1960s may cause water levels to drop several feet below normally observed levels. Above-average precipitation, such as occurred in the early 1970s, may cause water levels to rise higher than usual.

Hydrologic location also affects water-level range. Generally, the range is smallest near the ocean, and its bays, estuaries, or salt marshes. For example, observation well SDW 252, 0.3 miles from Cape Cod Bay, showed a range of only 2.6 feet; while well SDW 253, 6 miles from Cape Cod Bay, showed a range of 9.3 feet over the same 13-year period (fig. 3).

Explanation of the Technique

Weather and climate, which control ground-water recharge and evapotranspiration, are relatively uniform over all of Cape Cod. Also, most of Cape Cod consists of sandy deposits that have relatively uniform hydrologic properties, and water levels on the Cape are expected to respond similarly to similar hydrologic stresses. Because of these conditions, water-level changes at one location can be used to estimate water-level changes at other locations on Cape Cod.

The technique depends on maps of the annual range of water levels and is based on the assumption that water-level fluctuations at a septic system test site may be referenced to water-level fluctuations in index wells (fig. 4). Five zones of annual ranges of water levels (0-2 feet, 2-3 feet, 3-4 feet, 4-5 feet, and 5-6 feet) are mapped in color on the basis of water-level records from about 160 sites (plates 1-4). Periods of record for these 160 sites varied but the water-level range at a particular site, for the site's period of record, was within the annual range of the zone mapped. Areas where water levels best correlate with each of nine index wells are delineated on the maps by dashed-line boundaries (plates 1-4). The close similarity of water levels shown for two locations almost 30 miles apart on opposite sides of Cape Cod Bay is evidence of good correlation. Water levels from 146 wells correlate well with levels from the nine index wells; 87 percent of the correlation coefficients were greater than 0.8 out of a possible 1.0. Water levels from the nine index wells with 16 to 28 years of record were also used to develop tables of potential water-level rise for each index well (tables 1-9). The tables are matrices of water-level-adjustment values to be applied to water-level measurements from the test sites. Because the periods of record for the index wells generally exceed those for wells used to map the zones of annual ranges of ground-water level, values of potential water-level rise shown in the tables may exceed the ranges of the zones.

Because the water-level records for the index wells span the period of the highest (1972) and lowest (1965) annual precipitation recorded at Hyannis on Cape Cod over an 86-year period, the adjustment tables are considered representative of the ground-water level extremes during that 86-year period. Also, a test of the technique for 49 sites showed that over a 5-year period water levels exceeded the estimated high water level at only 8 percent of the sites, and the errors were less than 0.75 foot.

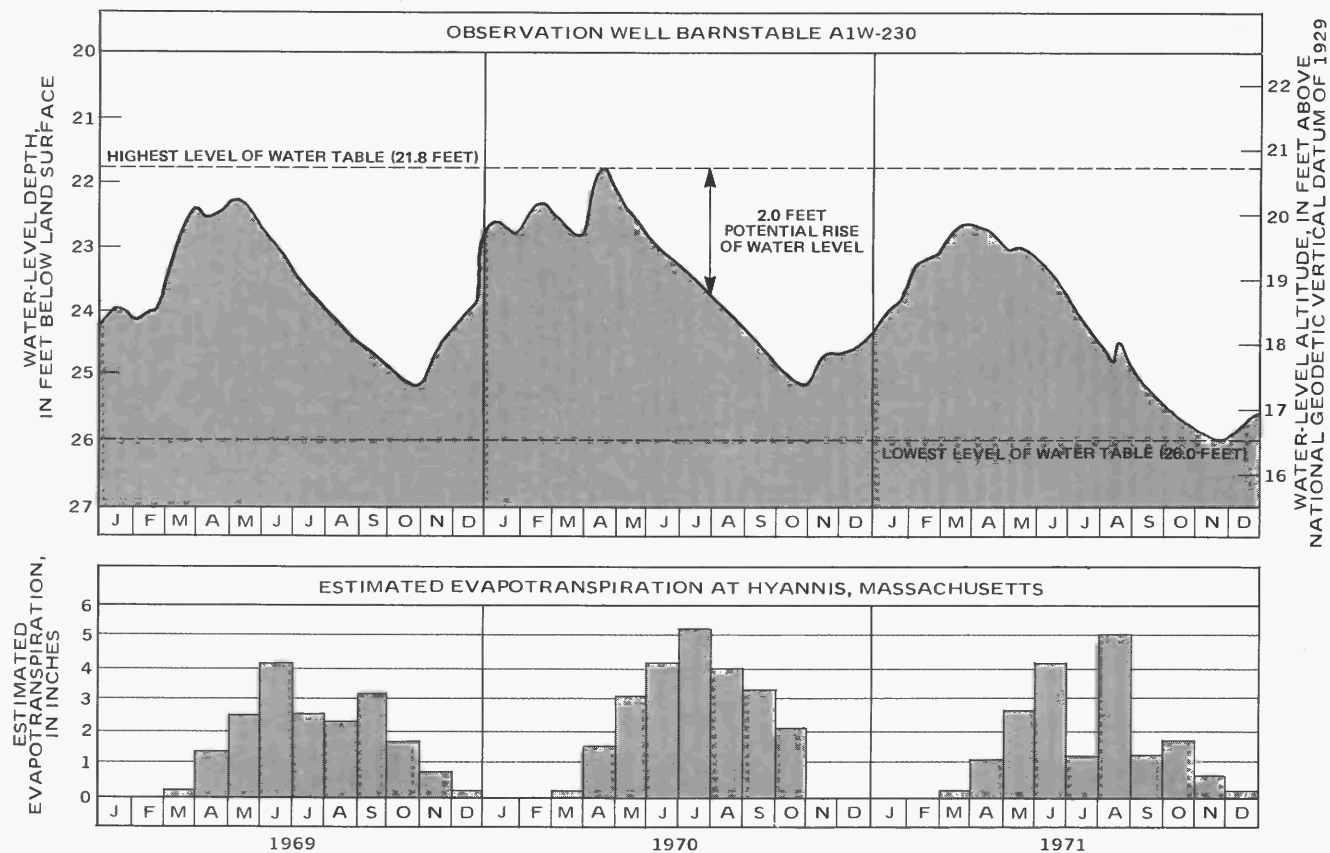


Figure 2. Seasonal water-level fluctuations and potential water-level rise.

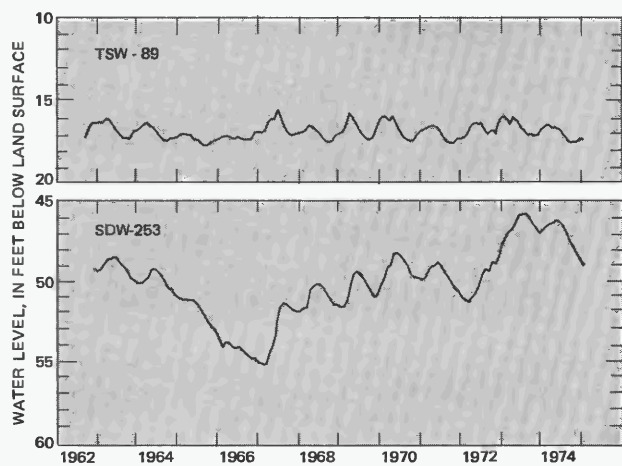


Figure 3. Water-level fluctuations in wells at 0.3 miles (TSW-89) and 6 miles (SDW-253) from Cape Cod Bay.

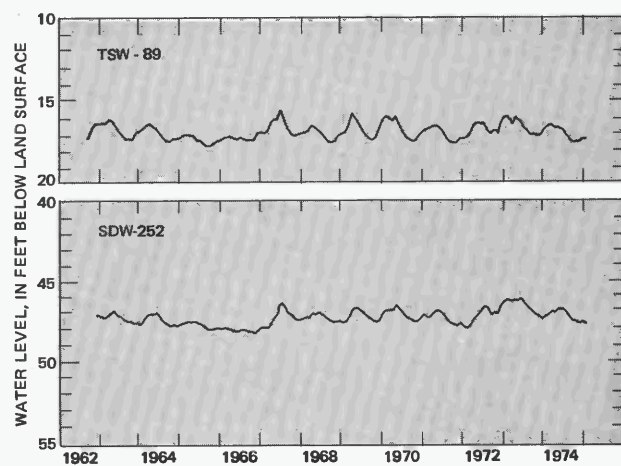


Figure 4. Similarity of water-level fluctuations in two wells about 28 miles apart but close to Cape Cod Bay.

HOW TO ESTIMATE HIGH GROUND-WATER LEVELS

Step 1. Measure Depth to Water at the Test Site

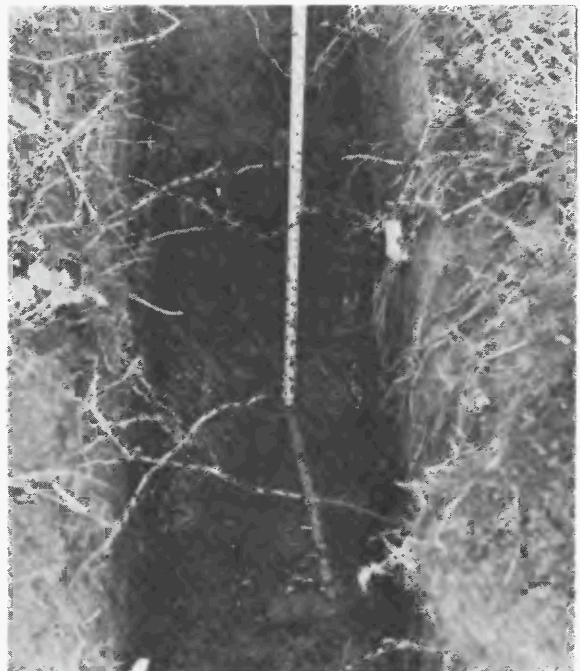
Measure the depth to water below the land surface and record on computation form (fig. 5.) Make measurement to the nearest one-tenth of a foot (fig. 6). Take note of soil conditions. Sites should be inspected for layers of silt, clay, or till

prior to attempting to estimate water levels. This technique is valid only in sand and gravel.

On June 21, 1981, the depth to water was 10.4 feet.

Permit Number: _____ Date: _____	
Completed by: _____	
HIGH GROUND-WATER LEVEL COMPUTATION	
Site Location: _____ Lot No. _____	
Owner: _____ Address: _____	
Contractor: _____ Address: _____	
Notes: _____	
STEP 1	Measure depth to water table to nearest 1/10 ft. _____ Date <u>6/21/81</u> 10.4 month/day/year
STEP 2	Using Water-Level Range Zone and Index Well Map locate site and determine: (A) Appropriate index well _____ (B) Water-level range zone _____
STEP 3	Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well _____ month/year
STEP 4	Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment _____
STEP 5	Estimate depth to high water by subtracting the water-level adjustment (STEP 4) from measured depth to water level at site (STEP 1) _____

Figure 5. Computation form, step 1.



Photographs courtesy of Cape Cod Planning and Economic Development Commission.

Figure 6. Measuring depth to water.

Step 2. Identify the Representative Index Well and Annual Water-Level Range for the Test Site

Locate the test site on the "Annual Ranges of Ground-Water Level and Index-Well Areas for Cape Cod" maps (plates 1-4) accompanying this report. Figure 8 shows an example of locating a site on a plate. (In some areas of Cape Cod, this estimation procedure cannot be used owing to unsuitable soil such as silt and clay or till. These areas are not colored on the maps of this report.)

Step 2A. Determine the Appropriate Index Well for the Site (as in fig. 8) and enter the well number on computation form (fig. 7)

Step 2B. Determine the Annual Water-Level Range Zone in Which the Site is Located (fig. 8) and Enter the Zone Letter on Computation Form (fig. 7)

Figure 8 shows that the (example) test site is in the area indexed to well TSW-89 and is in zone B.

Permit Number: _____ Date: _____
Completed by: _____

HIGH GROUND-WATER LEVEL COMPUTATION

Site Location: _____ Lot No. _____
Owner: _____ Address: _____
Contractor: _____ Address: _____
Notes: _____

STEP 1 Measure depth to water table to nearest 1/10 ft. _____ Date 6/21/81 10.4
month/day/year

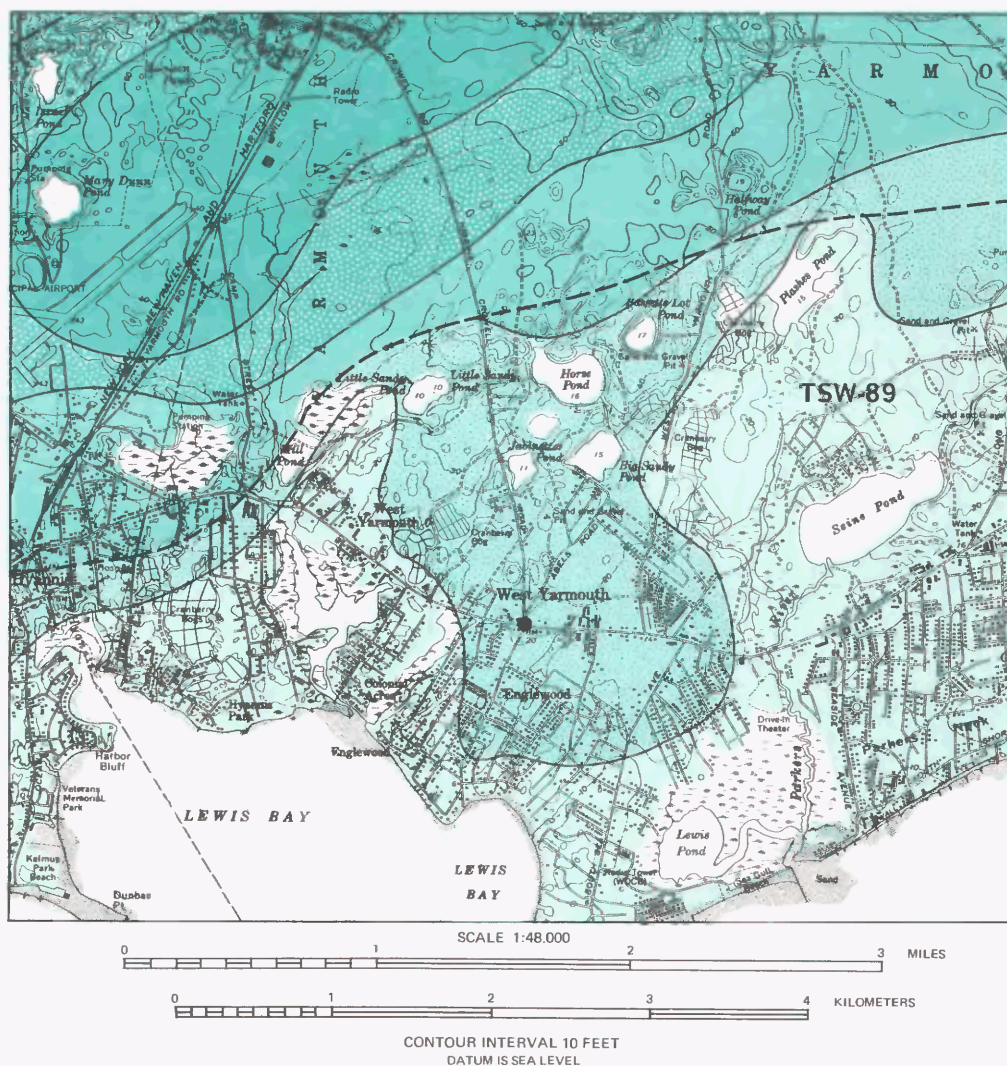
STEP 2 Using Water-Level Range Zone and Index Well Map locate site and determine:
(A) Appropriate index well _____ TSW-89
(B) Water-level range zone _____ B

STEP 3 Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well _____ month/year

STEP 4 Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment _____

STEP 5 Estimate depth to high water by subtracting the water-level adjustment (STEP 4) from measured depth to water level at site (STEP 1) _____

Figure 7. Computation form, step 2.



EXPLANATION

Annual range of
ground-water level, in feet

Zone	A	0 - 2
	B	2 - 3
	C	3 - 4
	D	4 - 5
	E	5 - 6

TSW-89 Index observation well to be used for
area delineated by dashed line.

● Test site

Figure 8. Example of map with site indicated.

Step 3. Determine Current Depth to Water Level for Index Well

The current depth to water level for the index well can be obtained from the U.S. Geological Survey report, "Current Water Resources Conditions in Central New England", which is issued each month by the U.S. Geological Survey¹. Record the month and year and (index well) water level for the current depth to water in the index well on the computations form (fig. 9). Using the "Summary of

Ground-Water Levels" table from that report (fig. 10), determine the depth to water in the appropriate index well that was recorded in STEP 2 for the month in which depth to water was measured at the test site. Figure 10 shows that in June 1981 the water level in well TSW-89, the index well for this area, was 12.20 feet below land surface.

Permit Number: _____ Date: _____
Completed by: _____

HIGH GROUND-WATER LEVEL COMPUTATION

Site Location: _____ Lot No. _____
Owner: _____ Address: _____
Contractor: _____ Address: _____
Notes: _____

STEP 1 Measure depth to water table to nearest 1/10 ft. Date 6/21/81 10.4

STEP 2 Using Water-Level Range Zone and Index Well Map locate site and determine:
(A) Appropriate index well TSW-89
(B) Water-level range zone B

STEP 3 Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well 6/81 12.2

STEP 4 Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment

STEP 5 Estimate depth to high water by subtracting the water-level adjustment (STEP 4) from measured depth to water level at site (STEP 1)

Figure 9. Computation form, step 3.

SUMMARY OF GROUND-WATER LEVELS*					JUNE 1981	PROVISIONAL *****
WELL	START OF RECORD	NET CHANGE IN		DEPARTURE FROM JUNE AVERAGE (FEET)	WATER LEVEL BELOW LAND- SURFACE DATUM (FEET)	
		MONTH (FEET)	ONE YEAR (FEET)			
MASSACHUSETTS						
ACTON 158	1965	- 0.40	- 1.04	- 1.33	19.62	
BARNSTABLE 230	1957	• 0.18	- 0.61	- 1.06	24.26	
BARNSTABLE 247	1962	- 0.16	- 1.59	- 2.19	26.04	
BOURNE 198	1962	- 0.38	- 0.71	- 0.98	35.79	
BREWSTER 21	1962	• 0.01	- 2.39	- 2.64	11.99	
CHATHAM 138	1962	• 0.09	- 0.80	- 1.55	24.83 ##	
DEDHAM 231	1965	- 2.47	- 0.45	- 1.22	8.97	
DOVER 10	1965	- 0.24	- 0.93	- 1.38	33.84 ##	
EAST BRIDGEWATER 30	1958	- 1.85	- 1.03	- 1.60	10.68	
FREETOWN 23	1964	• 0.03	- 1.42	- 1.53	14.47	
GRANVILLE 5	1965	- 0.17	- 2.01	- 1.01	33.29	
GREAT BARRINGTON 2	1951	- 2.88	• 0.75	- 0.45	11.86	
HAVERHILL 23	1960	- 0.79	• 0.26	- 0.30	12.12	
LOWELL 14	1939	- 1.39	- 0.81	- 0.96	13.03	
MONTAGUE 5	1942	- 1.28	- 1.60	- 1.01	4.61	
NORTHBROOK 38	1962	- 0.68	• 0.35	• 0.18	6.04	
NORTHBWIDGE 1	1965	- 0.30	- 0.13	- 0.22	3.13	
PITTSFIELD 51	1963	- 1.34	0.0	- 0.77	16.17	
PLYMOUTH 22	1956	0.0	- 1.83	- 2.95	26.36	
SANDWICH 252	1962	- 0.09	- 0.15	- 0.51	47.55	
SANDWICH 253	1962	- 0.16	- 1.39	- 1.97	51.13	
STERLING 1	1947	• 0.53	• 2.78	• 2.17	3.10 #	
TSW-89	1962	- 0.09	• 0.14	- 0.24	12.20	
WELLFLEET 17	1962	- 0.22	- 0.28	- 1.36	11.10	
WENHAM 76	1965	- 0.63	- 0.20	- 0.16	3.25	
WEST BROOKFIELD 10	1970	- 2.06	• 1.79	• 0.77	5.96	
WYMOUTH 2	1965	- 2.71	- 1.99	- 3.58	15.28 ##	
WILMINGTON 78	1951	- 0.40	• 0.19	- 0.03	8.05	
WINCHENDOM 13	1939	- 1.71	• 1.97	• 0.96	5.33	
WINCHESTER 14	1940	- 1.68	• 0.68	- 0.76	11.93	

Figure 10. Sample table from "Current Water Resources Conditions in Central New England".

¹ The U.S. Geological Survey report, "Current Water Resources Conditions in Central New England" is available from: U.S. Geological Survey, 150 Causeway St., Suite 1001, Boston, MA 02114, and from Cape Cod Planning and Economic Development Commission, Barnstable County Courthouse, Barnstable, MA 02630.

Step 4. Determine Water-Level Adjustment

Refer to the water-level-adjustment table, "Potential Water-Level Rise, in feet, for Use With Index Well...", (tables 1-9) in the back of this report for the appropriate index well (recorded in STEP 2A). Record the water-level adjustment value on the computation form (fig. 11). To determine the correct water-level adjustment, locate the current

water level for the index well in the left-hand column of the water-level adjustment table (fig. 12). Then read from left to right on the same horizontal row to the column of adjustment values for the zone recorded in STEP 2B. Figure 12 shows the water-level adjustment for the (sample) test site is 2.7 feet.

Permit Number: _____ Date: _____
Completed by: _____

HIGH GROUND-WATER LEVEL COMPUTATION

Site Location: _____ Lot No _____
Owner: _____ Address: _____
Contractor: _____ Address: _____
Notes: _____

STEP 1 Measure depth to water table to nearest 1/10 ft. Date 6/21/81 10.4
month/day/year

STEP 2 Using Water-Level Range Zone and Index Well Map locate site and determine:
(A) Appropriate index well TSW-89
(B) Water-level range zone B

STEP 3 Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well 6/81 12.2
month/year

STEP 4 Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment 2.7

STEP 5 Estimate depth to high water by subtracting the water-level adjustment (STEP 4) from measured depth to water level at site (STEP 1) _____

Figure 11. Computation form, step 4.

Potential water-level rise, in feet,
for use with index well Truro TSW-89

Water level
in well
(in feet below
land surface)

Zone A Zone B Zone C

10.4	0.0	0.0	0.0
10.5	.1	.1	.2
10.6	.2	.3	.4
10.7	.3	.4	.6
10.8	.4	.6	.8
10.9	.5	.7	1.0
11.0	.6	.9	1.2
11.1	.7	1.0	1.4
11.2	.8	1.2	1.6
11.3	.9	1.3	1.8
11.4	1.0	1.5	2.0
11.5	1.1	1.6	2.2
11.6	1.2	1.8	2.4
11.7	1.3	1.9	2.6
11.8	1.4	2.1	2.8
11.9	1.5	2.2	3.0
12.0	1.6	2.4	3.2
12.1	1.7	2.5	3.4
12.2	1.8	2.7	3.6
12.3	1.9	2.8	3.8
12.4	2.0	3.0	4.0
12.5	2.1	3.1	4.2
12.6	2.2	3.3	4.4
12.7	2.3	3.4	4.6
12.8	2.4	3.6	4.8
12.9	2.5	3.7	5.0
13.0	2.6	3.9	5.2

Figure 12. Example of water-level adjustment table.

Step 5. Estimate Depth to High Water Level at Site

Using the computation form (fig. 14), subtract the water-level-adjustment value determined in STEP 4 from the measured depth to water at the site recorded in STEP 1 to obtain the estimate of depth

to high water level and record on the computation form (fig. 13). Figure 13 shows the estimated depth to high water level at the (sample) test site is 7.7 feet below the land surface.

Permit Number: _____ Date: _____	
Completed by: _____	
HIGH GROUND-WATER LEVEL COMPUTATION	
Site Location: _____ Lot No. _____	
Owner: _____ Address: _____	
Contractor: _____ Address: _____	
Notes: _____	
STEP 1	Measure depth to water table to nearest 1/10 ft. _____ Date <u>6/21/81</u> <u>10.4</u> month/day/year
STEP 2	Using Water-Level Range Zone and Index Well Map locate site and determine: (A) Appropriate index well. _____ <u>TSW 88</u> (B) Water-level range zone. _____ <u>B</u>
STEP 3	Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well _____ <u>6/81</u> <u>12.2</u> month/year
STEP 4	Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment _____ <u>2.7</u>
STEP 5	Estimate depth to high water by subtracting the water-level adjustment (STEP 4) from measured depth to water level at site (STEP 1) _____ <u>7.7</u>

Figure 13. Computation form, step 5.

Permit Number: _____ Date: _____

Completed by: _____

HIGH GROUND-WATER LEVEL COMPUTATION

Site Location: _____ Lot No. _____

Owner: _____ Address: _____

Contractor: _____ Address: _____

Notes: _____

STEP 1	Measure depth to water table to nearest 1/10 ft.	Date _____ month/day/year	
STEP 2	Using Water-Level Range Zone and Index Well Map locate site and determine: Ⓐ Appropriate index well.....		
	Ⓑ Water-level range zone		
STEP 3	Using monthly report "Current Water Resources Conditions" determine current depth to water level for index well	_____ month/year	
STEP 4	Using Table of Water-level Adjustments for index well (STEP 2A), current depth to water level for index well (STEP 3), and water-level zone (STEP 2B) determine water-level adjustment		
STEP 5	Estimate depth to high water by subtracting the water- level adjustment (STEP 4) from measured depth to water level at site (STEP 1)		

Figure 14. Suggested computation form.

SUMMARY

Ground-water levels can be estimated for sand and gravel areas of Cape Cod using the procedure outlined in this report. An estimate can be made based upon a water-level measurement taken at any

season of the year. This method should not be applied in areas where layers of silt and clay or till are present.

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Table 1. Potential water-level rise, in feet, for use with index well Barnstable A1W-230.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	<u>Zone D</u>	<u>Zone E</u>
21.1	0.0	0.0	0.0	0.0	0.0
21.2	.0	.1	.1	.1	.1
21.3	.1	.1	.2	.2	.3
21.4	.1	.2	.3	.4	.4
21.5	.2	.3	.4	.5	.6
21.6	.2	.4	.5	.6	.7
21.7	.3	.4	.6	.7	.9
21.8	.3	.5	.7	.9	1.0
21.9	.4	.6	.8	1.0	1.2
22.0	.4	.7	.9	1.1	1.3
22.1	.5	.7	1.0	1.2	1.5
22.2	.5	.8	1.1	1.4	1.6
22.3	.6	.9	1.2	1.5	1.8
22.4	.6	1.0	1.3	1.6	1.9
22.5	.7	1.0	1.4	1.7	2.1
22.6	.7	1.1	1.5	1.9	2.2
22.7	.8	1.2	1.6	2.0	2.4
22.8	.8	1.3	1.7	2.1	2.5
22.9	.9	1.3	1.8	2.2	2.7
23.0	.9	1.4	1.9	2.4	2.8
23.1	1.0	1.5	2.0	2.5	3.0
23.2	1.0	1.6	2.1	2.6	3.1
23.3	1.1	1.6	2.2	2.7	3.3
23.4	1.1	1.7	2.3	2.9	3.4
23.5	1.2	1.8	2.4	3.0	3.6
23.6	1.2	1.9	2.5	3.1	3.7
23.7	1.3	1.9	2.6	3.2	3.9
23.8	1.3	2.0	2.7	3.4	4.0
23.9	1.4	2.1	2.8	3.5	4.2
24.0	1.4	2.2	2.9	3.6	4.3
24.1	1.5	2.2	3.0	3.7	4.5
24.2	1.5	2.3	3.1	3.9	4.6
24.3	1.6	2.4	3.2	4.0	4.8
24.4	1.6	2.5	3.3	4.1	4.9
24.5	1.7	2.5	3.4	4.2	5.1
24.6	1.7	2.6	3.5	4.4	5.2
24.7	1.8	2.7	3.6	4.5	5.4
24.8	1.8	2.8	3.7	4.6	5.5
24.9	1.9	2.8	3.8	4.7	5.7
25.0	1.9	2.9	3.9	4.9	5.8
25.1	2.0	3.0	4.0	5.0	6.0
25.2	2.0	3.1	4.1	5.1	6.1
25.3	2.1	3.1	4.2	5.2	6.3
25.4	2.1	3.2	4.3	5.4	6.4
25.5	2.2	3.3	4.4	5.5	6.6
25.6	2.2	3.4	4.5	5.6	6.7
25.7	2.3	3.4	4.6	5.7	6.9
25.8	2.3	3.5	4.7	5.9	7.0
25.9	2.4	3.6	4.8	6.0	7.2
26.0	2.4	3.7	4.9	6.1	7.3
26.1	2.5	3.7	5.0	6.2	7.5
26.2	2.5	3.8	5.1	6.4	7.6
26.3	2.6	3.9	5.2	6.5	7.8
26.4	2.6	4.0	5.3	6.6	7.9
26.5	2.7	4.0	5.4	6.7	8.1
26.6	2.7	4.1	5.5	6.9	8.2
26.7	2.8	4.2	5.6	7.0	8.4

Table 2. Potential water-level rise, in feet, for use with index well Barnstable A1W-247.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	Zone D
21.0	0.0	0.0	0.0	0.0
21.1	.1	.1	.1	.2
21.2	.1	.2	.3	.3
21.3	.2	.3	.4	.5
21.4	.3	.4	.5	.7
21.5	.3	.5	.7	.8
21.6	.4	.6	.8	1.0
21.7	.5	.7	.9	1.2
21.8	.5	.8	1.1	1.3
21.9	.6	.9	1.2	1.5
22.0	.7	1.0	1.3	1.7
22.1	.7	1.1	1.5	1.8
22.2	.8	1.2	1.6	2.0
22.3	.9	1.3	1.7	2.2
22.4	.9	1.4	1.9	2.3
22.5	1.0	1.5	2.0	2.5
22.6	1.1	1.6	2.1	2.7
22.7	1.1	1.7	2.3	2.8
22.8	1.2	1.8	2.4	3.0
22.9	1.3	1.9	2.5	3.2
23.0	1.3	2.0	2.7	3.3
23.1	1.4	2.1	2.8	3.5
23.2	1.5	2.2	2.9	3.7
23.3	1.5	2.3	3.1	3.8
23.4	1.6	2.4	3.2	4.0
23.5	1.7	2.5	3.3	4.2
23.6	1.7	2.6	3.5	4.3
23.7	1.8	2.7	3.6	4.5
23.8	1.9	2.8	3.7	4.7
23.9	1.9	2.9	3.9	4.8
24.0	2.0	3.0	4.0	5.0
24.1	2.1	3.1	4.1	5.2
24.2	2.1	3.2	4.3	5.3
24.3	2.2	3.3	4.4	5.5
24.4	2.3	3.4	4.5	5.7
24.5	2.3	3.5	4.7	5.8
24.6	2.4	3.6	4.8	6.0
24.7	2.5	3.7	4.9	6.2
24.8	2.5	3.8	5.1	6.3
24.9	2.6	3.9	5.2	6.5
25.0	2.7	4.0	5.3	6.7
25.1	2.7	4.1	5.5	6.8
25.2	2.8	4.2	5.6	7.0
25.3	2.9	4.3	5.7	7.2
25.4	2.9	4.4	5.9	7.3
25.5	3.0	4.5	6.0	7.5
25.6	3.1	4.6	6.1	7.7
25.7	3.1	4.7	6.3	7.8
25.8	3.2	4.8	6.4	8.0
25.9	3.3	4.9	6.5	8.2
26.0	3.3	5.0	6.6	8.3
26.1	3.4	5.1	6.8	8.5
26.2	3.5	5.2	6.9	8.7
26.3	3.6	5.3	7.0	8.9

Table 3. Potential water-level rise, in feet, for use with index well Bourne BHW-198.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>
30.4	0.0	0.0	0.0	33.4	2.0	3.0	4.0
30.5	.1	.1	.1	33.5	2.1	3.1	4.1
30.6	.1	.2	.3	33.6	2.1	3.2	4.3
30.7	.2	.3	.4	33.7	2.2	3.3	4.4
30.8	.3	.4	.5	33.8	2.3	3.4	4.5
30.9	.3	.5	.7	33.9	2.3	3.5	4.7
31.0	.4	.6	.8	34.0	2.4	3.6	4.8
31.1	.5	.7	.9	34.1	2.5	3.7	4.9
31.2	.5	.8	1.1	34.2	2.5	3.8	5.1
31.3	.6	.9	1.2	34.3	2.6	3.9	5.2
31.4	.7	1.0	1.3	34.4	2.7	4.0	5.3
31.5	.7	1.1	1.5	34.5	2.7	4.1	5.5
31.6	.8	1.2	1.6	34.6	2.8	4.2	5.6
31.7	.9	1.3	1.7	34.7	2.9	4.3	5.7
31.8	.9	1.4	1.9	34.8	2.9	4.4	5.9
31.9	1.0	1.5	2.0	34.9	3.0	4.5	6.0
32.0	1.1	1.6	2.1	35.0	3.1	4.6	6.1
32.1	1.1	1.7	2.3	35.1	3.1	4.7	6.3
32.2	1.2	1.8	2.4	35.2	3.2	4.8	6.4
32.3	1.3	1.9	2.5	35.3	3.3	4.9	6.5
32.4	1.3	2.0	2.7	35.4	3.3	5.0	6.6
32.5	1.4	2.1	2.8	35.5	3.4	5.1	6.8
32.6	1.5	2.2	2.9	35.6	3.5	5.2	6.9
32.7	1.5	2.3	3.1	35.7	3.6	5.3	7.0
32.8	1.6	2.4	3.2	35.8	3.6	5.4	7.2
32.9	1.7	2.5	3.3	35.9	3.7	5.5	7.3
33.0	1.7	2.6	3.5	36.0	3.8	5.6	7.4
33.1	1.8	2.7	3.6	36.1	3.8	5.7	7.6
33.2	1.9	2.8	3.7	36.2	3.9	5.8	7.7
33.3	1.9	2.9	3.9				

Table 4. Potential water-level rise, in feet, for use with index well Brewster BMW-21.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>
6.9	0.0	0.0	10.1	2.1	3.2
7.0	.1	.1	10.2	2.2	3.3
7.1	.1	.2	10.3	2.3	3.4
7.2	.2	.3	10.4	2.3	3.5
7.3	.3	.4	10.5	2.4	3.6
7.4	.3	.5	10.6	2.5	3.7
7.5	.4	.6	10.7	2.5	3.8
7.6	.5	.7	10.8	2.6	3.9
7.7	.5	.8	10.9	2.7	4.0
7.8	.6	.9	11.0	2.7	4.1
7.9	.7	1.0	11.1	2.8	4.2
8.0	.7	1.1	11.2	2.9	4.3
8.1	.8	1.2	11.3	2.9	4.4
8.2	.9	1.3	11.4	3.0	4.5
8.3	.9	1.4	11.5	3.1	4.6
8.4	1.0	1.5	11.6	3.1	4.7
8.5	1.1	1.6	11.7	3.2	4.8
8.6	1.1	1.7	11.8	3.3	4.9
8.7	1.2	1.8	11.9	3.3	5.0
8.8	1.3	1.9	12.0	3.4	5.1
8.9	1.3	2.0	12.1	3.5	5.2
9.0	1.4	2.1	12.2	3.6	5.3
9.1	1.5	2.2	12.3	3.6	5.4
9.2	1.5	2.3	12.4	3.7	5.5
9.3	1.6	2.4	12.5	3.8	5.6
9.4	1.7	2.5	12.6	3.8	5.7
9.5	1.7	2.6	12.7	3.9	5.8
9.6	1.8	2.7	12.8	4.0	5.9
9.7	1.9	2.8	12.9	4.0	6.0
9.8	1.9	2.9	13.0	4.1	6.1
9.9	2.0	3.0	13.1	4.2	6.2
10.0	2.1	3.1	13.2	4.2	6.3
			13.3	4.3	6.4

Table 5. Potential water-level rise, in feet, for use with index well Chatham CGW-138.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	<u>Zone D</u>
21.1	0.0	0.0	0.0	0.0
21.2	.1	.1	.1	.2
21.3	.1	.2	.3	.3
21.4	.2	.3	.4	.5
21.5	.3	.4	.5	.7
21.6	.3	.5	.7	.8
21.7	.4	.6	.8	1.0
21.8	.5	.7	.9	1.2
21.9	.5	.8	1.1	1.3
22.0	.6	.9	1.2	1.5
22.1	.7	1.0	1.3	1.7
22.2	.7	1.1	1.5	1.8
22.3	.8	1.2	1.6	2.0
22.4	.9	1.3	1.7	2.2
22.5	.9	1.4	1.9	2.3
22.6	1.0	1.5	2.0	2.5
22.7	1.1	1.6	2.1	2.7
22.8	1.1	1.7	2.3	2.8
22.9	1.2	1.8	2.4	3.0
23.0	1.3	1.9	2.5	3.2
23.1	1.3	2.0	2.7	3.3
23.2	1.4	2.1	2.8	3.5
23.3	1.5	2.2	2.9	3.7
23.4	1.5	2.3	3.1	3.8
23.5	1.6	2.4	3.2	4.0
23.6	1.7	2.5	3.3	4.2
23.7	1.7	2.6	3.5	4.3
23.8	1.8	2.7	3.6	4.5
23.9	1.9	2.8	3.7	4.7
24.0	1.9	2.9	3.9	4.8
24.1	2.0	3.0	4.0	5.0
24.2	2.1	3.1	4.1	5.2
24.3	2.1	3.2	4.3	5.3
24.4	2.2	3.3	4.4	5.5
24.5	2.3	3.4	4.5	5.7
24.6	2.3	3.5	4.7	5.8
24.7	2.4	3.6	4.8	6.0
24.8	2.5	3.7	4.9	6.2
24.9	2.5	3.8	5.1	6.3
25.0	2.6	3.9	5.2	6.5
25.1	2.7	4.0	5.3	6.7
25.2	2.7	4.1	5.5	6.8
25.3	2.8	4.2	5.6	7.0
25.4	2.9	4.3	5.7	7.2
25.5	2.9	4.4	5.9	7.3
25.6	3.0	4.5	6.0	7.5
25.7	3.1	4.6	6.1	7.7
25.8	3.1	4.7	6.3	7.8
25.9	3.2	4.8	6.4	8.0
26.0	3.3	4.9	6.5	8.2
26.1	3.3	5.0	6.6	8.3
26.2	3.4	5.1	6.8	8.5

Table 6. Potential water-level rise, in feet, for use with index well Sandwich SDW-252.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	Water Level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>
46.0	0.0	0.0	47.2	1.2	1.8
46.1	.1	.1	47.3	1.3	1.9
46.2	.2	.3	47.4	1.4	2.1
46.3	.3	.4	47.5	1.5	2.2
46.4	.4	.6	47.6	1.6	2.4
46.5	.5	.7	47.7	1.7	2.5
46.6	.6	.9	47.8	1.8	2.7
46.7	.7	1.0	47.9	1.9	2.8
46.8	.8	1.2	48.0	2.0	3.0
46.9	.9	1.3	48.1	2.1	3.1
47.0	1.0	1.5	48.2	2.2	3.3
47.1	1.1	1.6			

Table 7. Potential water-level rise, in feet, for use with index well Sandwich SDW-253.

Water level in well (in feet below land surface)	Zone A	Zone B	Zone C	Water level in well (in feet below land surface)	Zone A	Zone B	Zone C
45.8	0.0	0.0	0.0	50.5	3.2	4.7	6.2
45.9	.1	.1	.1	50.6	3.2	4.8	6.4
46.0	.1	.2	.3	50.7	3.3	4.9	6.5
46.1	.2	.3	.4	50.8	3.4	5.0	6.6
46.2	.3	.4	.5	50.9	3.4	5.1	6.8
46.3	.3	.5	.7	51.0	3.5	5.2	6.9
46.4	.4	.6	.8	51.1	3.6	5.3	7.0
46.5	.5	.7	.9	51.2	3.6	5.4	7.2
46.6	.5	.8	1.1	51.3	3.7	5.5	7.3
46.7	.6	.9	1.2	51.4	3.8	5.6	7.4
46.8	.7	1.0	1.3	51.5	3.8	5.7	7.6
46.9	.7	1.1	1.5	51.6	3.9	5.8	7.7
47.0	.8	1.2	1.6	51.7	4.0	5.9	7.8
47.1	.9	1.3	1.7	51.8	4.0	6.0	7.9
47.2	.9	1.4	1.9	51.9	4.1	6.1	8.1
47.3	1.0	1.5	2.0	52.0	4.2	6.2	8.2
47.4	1.1	1.6	2.1	52.1	4.3	6.3	8.3
47.5	1.1	1.7	2.3	52.2	4.3	6.4	8.5
47.6	1.2	1.8	2.4	52.3	4.4	6.5	8.6
47.7	1.3	1.9	2.5	52.4	4.5	6.6	8.7
47.8	1.3	2.0	2.6	52.5	4.5	6.7	8.9
47.9	1.4	2.1	2.8	52.6	4.6	6.8	9.0
48.0	1.5	2.2	2.9	52.7	4.7	6.9	9.1
48.1	1.6	2.3	3.0	52.8	4.7	7.0	9.3
48.2	1.6	2.4	3.2	52.9	4.8	7.1	9.4
48.3	1.7	2.5	3.3	53.0	4.9	7.2	9.5
48.4	1.8	2.6	3.4	53.1	4.9	7.3	9.7
48.5	1.8	2.7	3.6	53.2	5.0	7.4	9.8
48.6	1.9	2.8	3.7	53.3	5.1	7.5	9.9
48.7	2.0	2.9	3.8	53.4	5.1	7.6	10.1
48.8	2.0	3.0	4.0	53.5	5.2	7.7	10.2
48.9	2.1	3.1	4.1	53.6	5.3	7.8	10.3
49.0	2.2	3.2	4.2	53.7	5.3	7.9	10.5
49.1	2.2	3.3	4.4	53.8	5.4	8.0	10.6
49.2	2.3	3.4	4.5	53.9	5.5	8.1	10.7
49.3	2.4	3.5	4.6	54.0	5.5	8.2	10.9
49.4	2.4	3.6	4.8	54.1	5.6	8.3	11.0
49.5	2.5	3.7	4.9	54.2	5.7	8.4	11.1
49.6	2.6	3.8	5.0	54.3	5.7	8.5	11.3
49.7	2.6	3.9	5.2	54.4	5.8	8.6	11.4
49.8	2.7	4.0	5.3	54.5	5.9	8.7	11.5
49.9	2.8	4.1	5.4	54.6	5.9	8.8	11.7
50.0	2.8	4.2	5.6	54.7	6.0	8.9	11.8
50.1	2.9	4.3	5.7	54.8	6.1	9.0	11.9
50.2	3.0	4.4	5.8	54.9	6.1	9.1	12.1
50.3	3.0	4.5	6.0	55.0	6.2	9.2	12.2
50.4	3.1	4.6	6.1	55.1	6.3	9.3	12.3

Table 8. Potential water-level rise, in feet, for use with index well Truro TSW-89.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>
10.4	0.0	0.0	0.0	11.8	1.4	2.1	2.8
10.5	.1	.1	.2	11.9	1.5	2.2	3.0
10.6	.2	.3	.4	12.0	1.6	2.4	3.2
10.7	.3	.4	.6	12.1	1.7	2.5	3.4
10.8	.4	.6	.8	12.2	1.8	2.7	3.6
10.9	.5	.7	1.0	12.3	1.9	2.8	3.8
11.0	.6	.9	1.2	12.4	2.0	3.0	4.0
11.1	.7	1.0	1.4	12.5	2.1	3.1	4.2
11.2	.8	1.2	1.6	12.6	2.2	3.3	4.4
11.3	.9	1.3	1.8	12.7	2.3	3.4	4.6
11.4	1.0	1.5	2.0	12.8	2.4	3.6	4.8
11.5	1.1	1.6	2.2	12.9	2.5	3.7	5.0
11.6	1.2	1.8	2.4	13.0	2.6	3.9	5.2
11.7	1.3	1.9	2.6				

Table 9. Potential water-level rise, in feet, for use with index well Wellfleet WNW-17.

Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>	Water level in well (in feet below land surface)	<u>Zone A</u>	<u>Zone B</u>	<u>Zone C</u>
7.3	0.0	0.0	0.0	10.1	1.4	2.1	2.8
7.4	.0	.1	.1	10.2	1.4	2.2	2.9
7.5	.1	.1	.2	10.3	1.5	2.2	3.0
7.6	.1	.2	.3	10.4	1.5	2.3	3.1
7.7	.2	.3	.4	10.5	1.6	2.4	3.2
7.8	.2	.4	.5	10.6	1.6	2.5	3.3
7.9	.3	.4	.6	10.7	1.7	2.5	3.4
8.0	.3	.5	.7	10.8	1.7	2.6	3.5
8.1	.4	.6	.8	10.9	1.8	2.7	3.6
8.2	.4	.7	.9	11.0	1.8	2.8	3.7
8.3	.5	.7	1.0	11.1	1.9	2.8	3.8
8.4	.5	.8	1.1	11.2	1.9	2.9	3.9
8.5	.6	.9	1.2	11.3	2.0	3.0	4.0
8.6	.6	1.0	1.3	11.4	2.0	3.1	4.1
8.7	.7	1.0	1.4	11.5	2.1	3.1	4.2
8.8	.7	1.1	1.5	11.6	2.1	3.2	4.3
8.9	.8	1.2	1.6	11.7	2.2	3.3	4.4
9.0	.8	1.3	1.7	11.8	2.2	3.4	4.5
9.1	.9	1.3	1.8	11.9	2.3	3.4	4.6
9.2	.9	1.4	1.9	12.0	2.3	3.5	4.7
9.3	1.0	1.5	2.0	12.1	2.4	3.6	4.8
9.4	1.0	1.6	2.1	12.2	2.4	3.7	4.9
9.5	1.1	1.6	2.2	12.3	2.5	3.7	5.0
9.6	1.1	1.7	2.3	12.4	2.5	3.8	5.1
9.7	1.2	1.8	2.4	12.5	2.6	3.9	5.2
9.8	1.2	1.9	2.5	12.6	2.6	4.0	5.3
9.9	1.3	1.9	2.6	12.7	2.7	4.0	5.4
10.0	1.3	2.0	2.7	12.8	2.7	4.1	5.5