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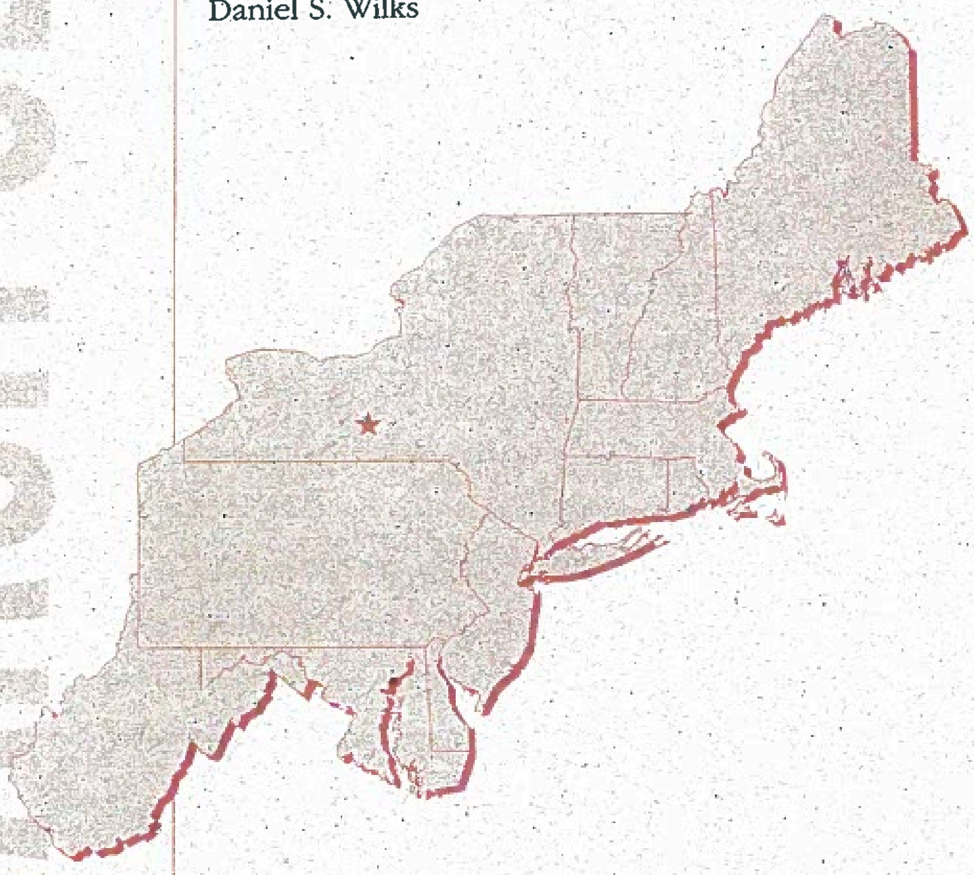
Atlas of Short-Duration Precipitation Extremes for the Northeastern United States and Southeastern Canada

Megan McKay
Daniel S. Wilks



Cornell University
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Publication No. RR 95-1
March 1995

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CONTENTS

INTRODUCTION

The results in the *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* [Wilks and Cember 1993] are based on data which were measured on a daily basis. Because some users require estimates of extreme precipitation amounts occurring over periods shorter than one day, a table of standard adjustment factors was included in that publication. The table allows the transformation of daily extreme precipitation values to estimates for shorter accumulation periods. These standard adjustment factors, from Huff and Angel [1992], were based on analyses of data from the midwestern U.S. and did not contain any spatial structure. In investigating the suitability of these empirical factors for the northeastern U.S., we found that on average for shorter periods (one, two, and three hours) the factors tended to overestimate the extreme amounts. In addition, some spatial differences were found for these adjustment factors within this region.

DATA AND METHODOLOGY

Hourly precipitation data for the northeastern U.S. were obtained from the archives of the Northeast Regional Climate Center (Ithaca, New York). These data were measured at both first-order National Weather Service stations and some cooperative network stations. Of the 256 stations with at least 30 years of data, only two station records exceeded 45 years in length. To ensure the quality of these hourly data, 1-day amounts were computed using the daily observing time at each station, and these were compared to the reported daily measurements. Any cases where the sum of the hourly amounts exceeded the daily reported amount by more than one inch were evaluated by a human analyst. Also investigated were any reported rainfall amounts of 4 inches or more in one hour.

In order to compare with the previously published adjustment factors, ratios of extreme precipitation amounts over the 1-, 2-, 3-, 6-, 12-, 18-, and 24-hour accumulation periods, to 1-day (fixed observation time) extreme precipitation amounts, were constructed. In forming the ratios, partial duration series were extracted from the data at each station. To achieve this, a sliding window corresponding to the length of each time period was used. For example, for the 18-hour ratio the largest accumulations over eighteen consecutive hours were extracted from the data set. Care was taken to exclude any overlapping sequences, so that a given hourly observation could not be used in more than one 18-hour extreme amount. This restriction was also enforced in the construction of partial duration series for the other accumulation periods. For the 1-day extreme precipitation amounts, an 8 AM observing time was adopted because the majority of cooperative network stations measure at this time. This means a fixed window running from the observation ending at 9 AM the previous day to the 8 AM observation on the current day was used instead of a sliding window. In developing these partial duration sets, a total number of values equal to the number of years in the station record were extracted, allowing for the possibility that more than one value could be obtained from the same year.

These partial duration sets were then individually ranked, and divided by the corresponding ranked 1-day amount. The resulting ratios were then averaged for each station. To compare these values with those of Huff and Angel we further averaged the ratios over all the individual stations in the northeast region. These averaged values are consistently smaller than those reported by Huff and Angel, except for the 18- and 24-hour accumulation periods, and the differences decrease monotonically with the length of accumulation period (Table 1).

As a side note, the Huff and Angel factors presented in the *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* were transformed from ratios based on 24-hour (variable observation time) amounts into 1-day amounts using the empirical factor of 1.13, but this does not affect the results presented here. The ratios for the northeast region based on 24-hour amounts still show that the Huff and Angel factors overestimate extreme precipitation amounts for the shorter accumulation periods at stations in the northeastern U.S. In addition, using an observation time of either midnight or 5 PM changes the Northeast average ratios presented in Table 1 on the order of only 0.01.

Table 1. Empirical factors for converting 1-day (fixed observation time) extreme precipitation amounts into short-duration extreme precipitation amounts calculated by averaging over the northeast region, in comparison to those given by Huff and Angel [1992].

Duration	Northeast average	Huff and Angel
1-hour	0.43	0.53
2-hour	0.54	0.66
3-hour	0.62	0.72
6-hour	0.79	0.85
12-hour	0.97	0.98
18-hour	1.07	1.06
24-hour	1.13	1.13

SPATIAL VARIABILITY

To analyze the spatial variability of the adjustment factors over the northeast region, multiple regression equations were developed to estimate the short-duration extreme precipitation amounts, using as predictors the 1-day extreme precipitation amount, and station latitude, longitude and elevation.

Based on all the stations, the 1-hour extreme precipitation amount (inches) for any return period at a specific station may be estimated using:

$$P_1 = P_{DAY}\left[\underset{(3.9*10^{-2})}{-6.9*10^{-1}} - \underset{(3.2*10^{-4})}{2.0*10^{-2}}\, P_{DAY} + \underset{(4.9*10^{-4})}{3.4*10^{-3}}\,\phi + \underset{(2.7*10^{-4})}{1.4*10^{-2}}\,\lambda - \underset{(7.0*10^{-7})}{1.9*10^{-5}}\,z\right], \quad (1)$$

the 2-hour extreme precipitation amount (inches) using:

$$P_2 = P_{DAY}\left[-5.5*10^{-1} - 2.4*10^{-2} P_{DAY} + 2.4*10^{-3}\phi + 1.4*10^{-2}\lambda - 2.1*10^{-5} z\right], \quad (2)$$

$$\quad (4.6*10^{-2})\ (3.7*10^{-4})\qquad (5.9*10^{-4})\ (3.3*10^{-4})\ (8.4*10^{-7})$$

and the 3-hour extreme precipitation amount (inches) using:

$$P_3 = P_{DAY}\left[-1.8*10^{-1} - 2.6*10^{-2} P_{DAY} + 1.2*10^{-2}\lambda - 2.0*10^{-5} z\right], \quad (3)$$

$$\quad (5.2*10^{-2})\ (4.2*10^{-4})\qquad (3.7*10^{-4})\ (9.4*10^{-7})$$

where ϕ, λ, and z are the station latitude (degrees), longitude (degrees West), and elevation (feet), respectively, and P_{DAY} is the 1-day (fixed observation time) extreme precipitation amount in inches. The estimated standard errors are shown in parenthesis below each coefficient to give an indication of the uncertainty. Note that the latitude variable is not included in Eq. 3 because its coefficient is not significantly different from zero.

For example: To compute the 2-hour, 25-year return period amount for Ithaca, New York, we need to know the station location and elevation, and 1-day 25-year extreme precipitation amount. These values are $\phi = 42.45°$, $\lambda = 76.45°$, $z = 955$ ft, and $P_{DAY} = 3.8$ inches. Putting these values into Eq. 2, we obtain the estimate

$$P_2 = 3.8*\left[-5.5*10^{-1} - 2.4*10^{-2}(3.8) + 2.4*10^{-3}(42.45) + 1.4*10^{-2}(76.45) - 2.1*10^{-5}(955)\right]$$

$$= 1.94 \text{ inches}.$$

To compare the performance of these equations to the empirical factors presented by Huff and Angel, and the averaged factors calculated from the data for the northeast region (Table 1), we examined how well each could specify the short-duration extreme precipitation amqunts from the 1-day values at the locations for which hourly data are available. These results are summarized in terms of the root-mean square errors (RMSE) in Table 2. For completeness, the RMSE for all the hourly periods (except 24 hours) are included in Table 2, even though the 6-, 12-, and 18-hour regression equations have not been shown. For the 1-, 2-, and 3-hour durations in the northeast region of the United States, the regression equations perform better than the empirical factors given by Huff and Angel, and somewhat better than those averaged over the area. For the 6-hour duration, there is very little difference between the performance of the regression equation (not shown) and the average for the Northeast, but both perform better than the Huff and Angel empirical factor, while for the 12- and 18-hour durations, there is very little difference between any of the

Table 2: Root Mean Squared Errors (inches) for the multiple regression equations, average values for the northeast region, and Huff and Angel [1992] empirical factors, for converting 1-day extreme precipitation amounts into short-duration extreme precipitation amounts for northeastern U.S. stations at which hourly precipitation data are available.

Duration	Regression	Northeast average	Huff and Angel
1-hour	0.15	0.23	0.39
2-hour	0.19	0.26	0.46
3-hour	0.21	0.28	0.42
6-hour	0.23	0.25	0.32
12-hour	0.22	0.22	0.23
18-hour	0.20	0.21	0.21

performances. The differences between the Huff and Angel factors and the regression equations for the shorter durations may derive from the difference in the type of storm events which produce the extreme precipitation in each area. In the Midwest, these storms tend to produce more rain in shorter periods of time due to more vigorous convection than in the Northeast.

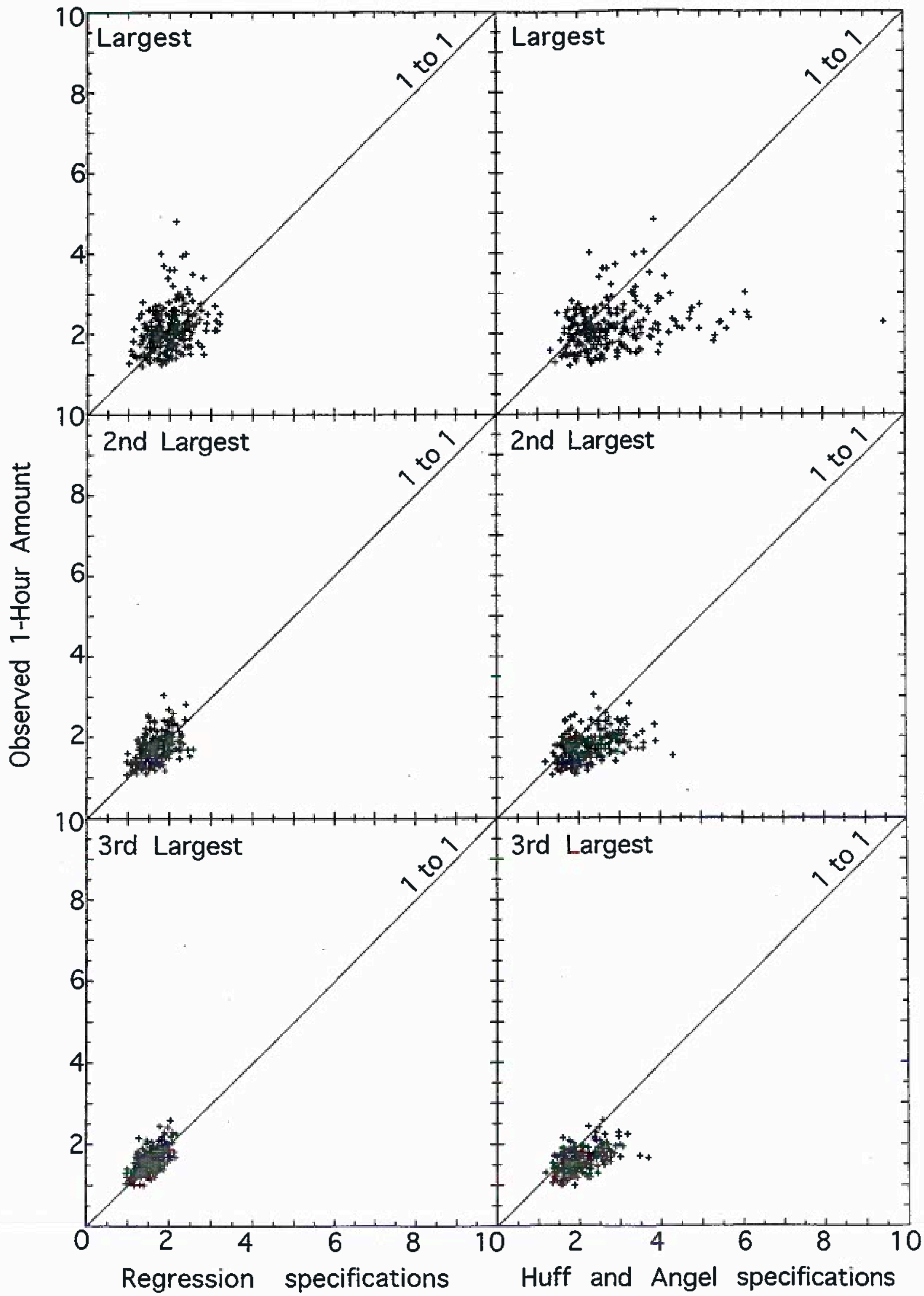
To ensure the validity of using the regression equations, a random sample of the 256 stations was used to develop a set of equations to estimate the short duration extreme precipitation amounts. The sample was determined by simulating a coin flip for each station to be included or not, which resulted in 117 stations being chosen. Equations based on this sub-sample are similar to Eqs. 1-3 above, but vary slightly in the coefficients for each of the variables. Simple averages of the ratios were also calculated over the 117-member subset and were the same as the Northeast averages for the full 256-station set given in Table 1. The remaining 139 stations were then used to evaluate the validity of the equations (Table 3). As can be seen, especially for the short durations (1, 2, and 3 hrs), the regression equations still performed better than either of the average empirical factors on the validation set. There is very little difference between the RMSE of the dependant and the validation data, which implies that the regression Eqs. 1-3 have not been overfit.

Table 3: Similar to Table 2; Root Mean Squared Errors (inches) for multiple regression equations developed using a random sample of stations for both the developmental data (SAMP) and the reserved independent validation data (VALID). Also shown are the corresponding RMSE values for the other empirical factors.

Duration	Regression		Northeast average		Huff and Angel	
	SAMP	VALID	SAMP	VALID	SAMP	VALID
1-hour	0.16	0.15	0.25	0.21	0.41	0.37
2-hour	0.20	0.21	0.28	0.25	0.48	0.44
3-hour	0.21	0.22	0.29	0.26	0.44	0.40
6-hour	0.23	0.23	0.25	0.24	0.33	0.31
12-hour	0.20	0.22	0.21	0.23	0.22	0.23
18-hour	0.21	0.19	0.21	0.20	0.21	0.20

Another indication of the performance of the regression equations is given in Figure 1, in which specifications and observations of the largest three 1-hourly amounts at each station are compared. The left-hand panels show specifications using the regression Eq. 1, and the right-hand panels show the results for the Huff and Angel empirical factor. Ideally, all the points would fall on the 1-1 lines. As expected, the Huff and Angel empirical factor tends to overestimate the observed value for each of the three largest points, while the regression equation yields specifications closer to the observed values. While in some extreme cases the regression Eq. 1 seems to underpredict the 1-hour extreme precipitation amount (and often in these cases the Huff and Angel empirical factor also underpredicts), the stronger grouping of values around the 1-1 line indicates that the regression equation does specify extreme precipitation amounts better than the Huff and Angel empirical factor for the northeastern region. The 2- and 3-hour amounts give similar results to that shown in Fig. 1, while for the longer accumulation periods, there is less difference between the two specifications.

Figure 1: Observations of the three largest 1-hourly amounts at each hourly station in the northeastern U.S. compared to the specifications by the regression Eq. (1) [left panels] and the Huff and Angel empirical factor [right panels].



It should also be noted that neither the Northeast averaged empirical factors nor the regression equations exhibited any significant change over different return periods in the hourly data set. That is, the regression coefficients and the Northeast average ratios remain approximately the same regardless of whether the largest, second-largest, etc., precipitation amount is being estimated.

OTHER CONVERSIONS

For completeness we have also investigated the conversions from calendar-day observations to maximum period amounts (Table 4), and from annual maximum amounts to partial duration amounts (Table 5).

For examining the conversion from calendar-day to maximum periods, a method similar to that described above was used. Partial duration sets with a sliding window for 48, 72, 120, and 240 hours were ranked and compared to ranked partial duration amounts for fixed windows of 2, 3, 5, and 10 days, respectively. These produced ratios which are not significantly different than those given by Huff and Angel [1992], and shown in Table 4.

Table 4: Empirical factors for converting calendar-day extreme precipitation amounts into maximum period hourly extreme precipitation amounts given by Huff and Angel [1992], and verified also using northeastern U.S. data.

Day into Hour	Huff and Angel
2-day into 48-hours	1.05
3-day into 72-hours	1.02
5-day into 120-hours	1.01
10-day into 240-hours	1.01

Annual maximum sets were created similarly to partial duration sets, but only allowing one extreme event from each year to be included in the series. In this comparison there is a strong dependence upon return period. Therefore, instead of averaging over the extreme events for each station, values were extracted from the ranked partial duration sets corresponding to the recurrence intervals of 2, 5, and 10 years. These were then divided by the corresponding values in the annual sets, for each station, which were then averaged together to produce ratios for the northeast region. Again, the resulting northeast regional average ratios did not show any appreciable differences from those presented by Huff and Angel [1992], and shown in Table 5. For recurrence intervals longer than about 10 years, the annual maximum and partial-duration amounts are essentially equivalent.

Table 5: Empirical adjustment factors that can be used to transform annual maximums into partial duration amounts. From Huff and Angel [1992], and verified also using northeastern U.S. data.

Duration	2-year	5-year	10-year
24-hour	1.13	1.05	1.01
48-hour	1.09	1.02	1.01
120-hour	1.08	1.01	1.01
240-hour	1.08	1.01	1.01

MAPS

For convenience we include maps of estimated 1-, 2-, and 3-hour extreme precipitation amounts for the same return periods presented in the *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada*. These maps are based on the 1-day accumulation amounts shown in that atlas, and transformed into estimated short-duration extreme amounts with the regression Eqs. 1-3 presented above, for 1-, 2-, and 3-hour accumulation periods, respectively. Because the 6-, 12-, 18-, and 24-hour accumulation period maps are only scalar transformations of the 1-day extreme precipitation amounts using the Northeast average empirical factors (Table 1), they are not presented here. As a reminder, the 1-day accumulation amounts were specified by fitting the daily extreme precipitation data using the Beta-P probability distribution, and interpolating or extrapolating to the various return periods. For more details and a list of the stations used, please see the *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada*. The same interpolation, gridding, smoothing and contouring techniques were used as in that publication.

ACKNOWLEDGMENTS

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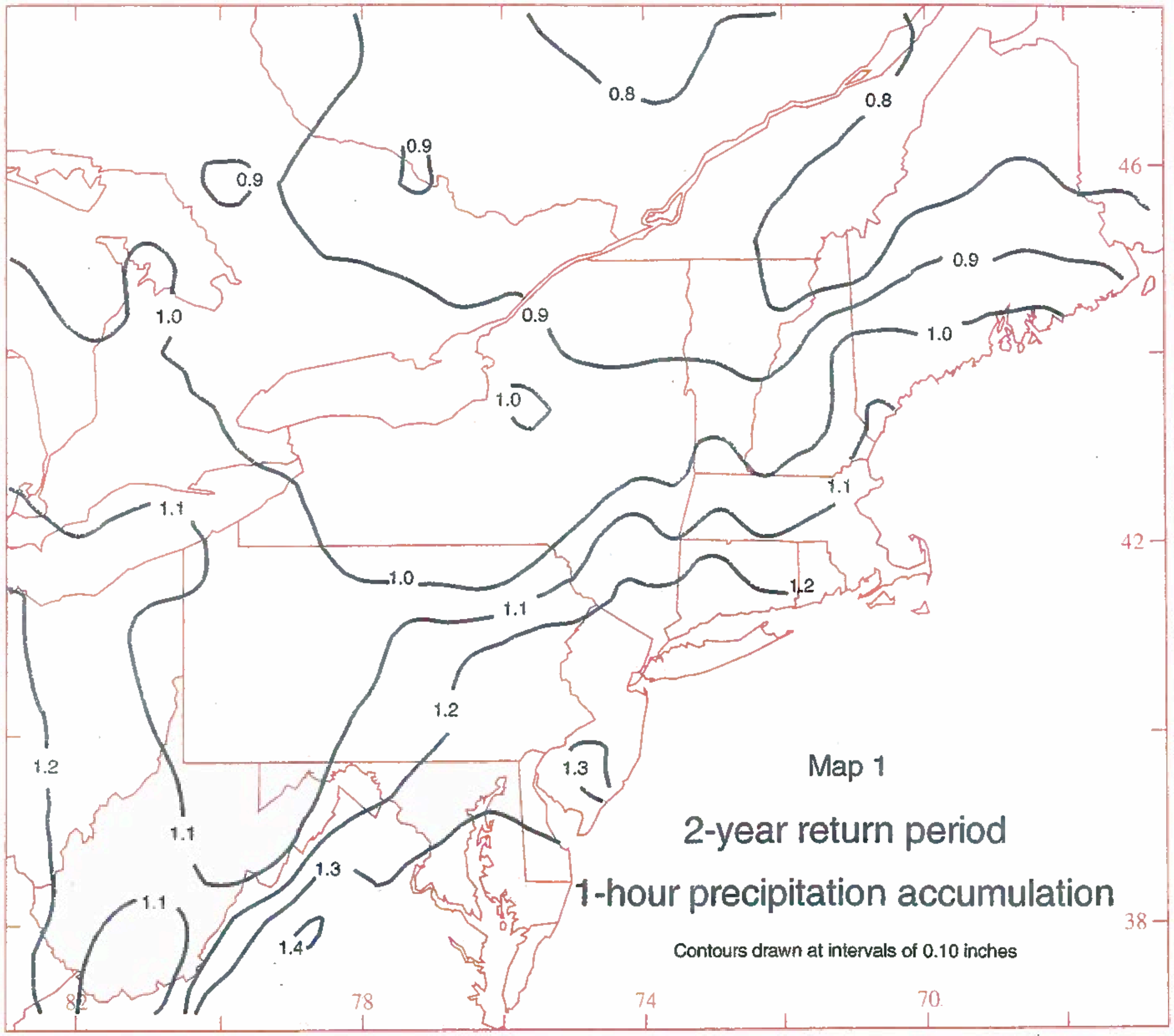
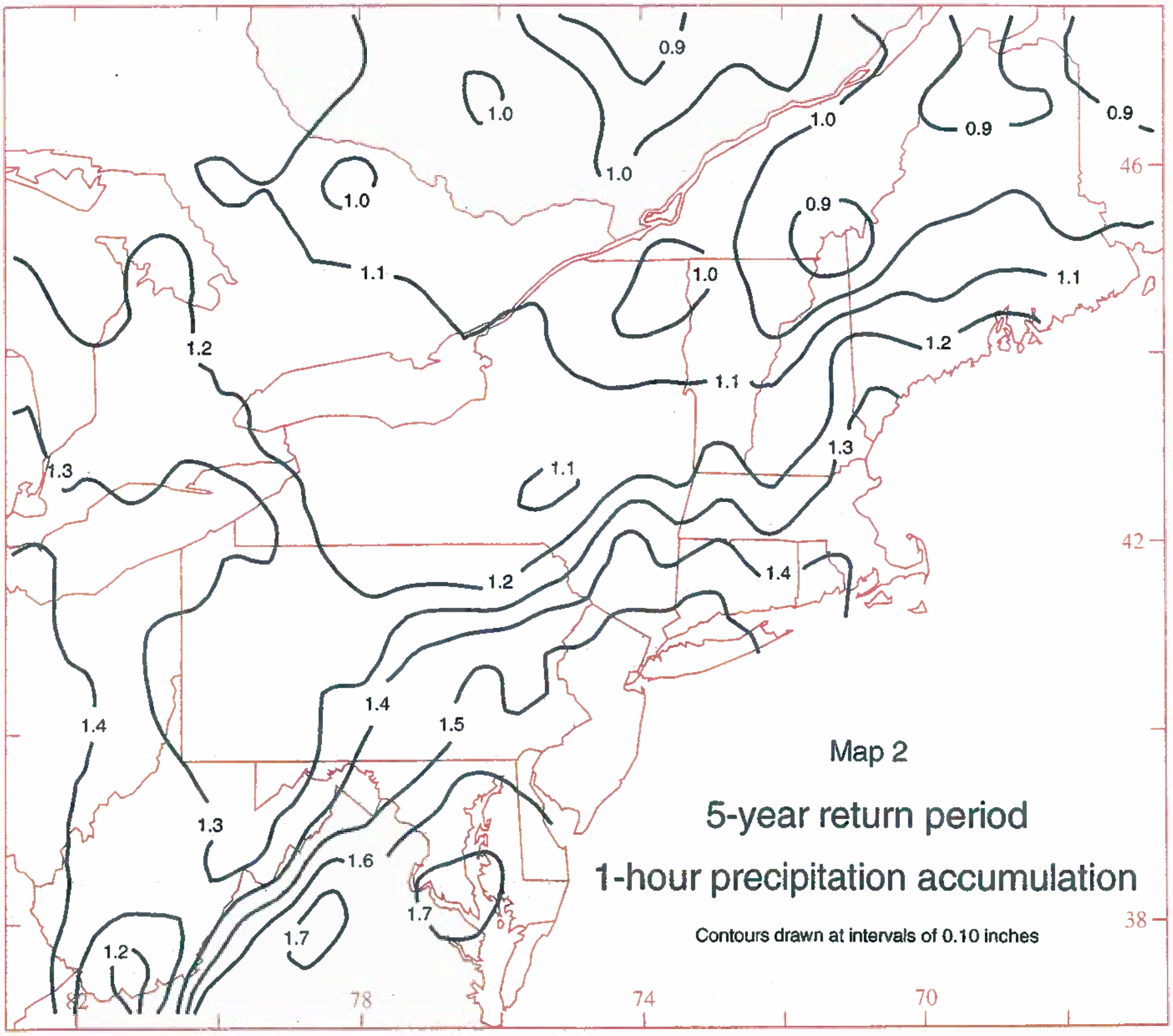
REFERENCES

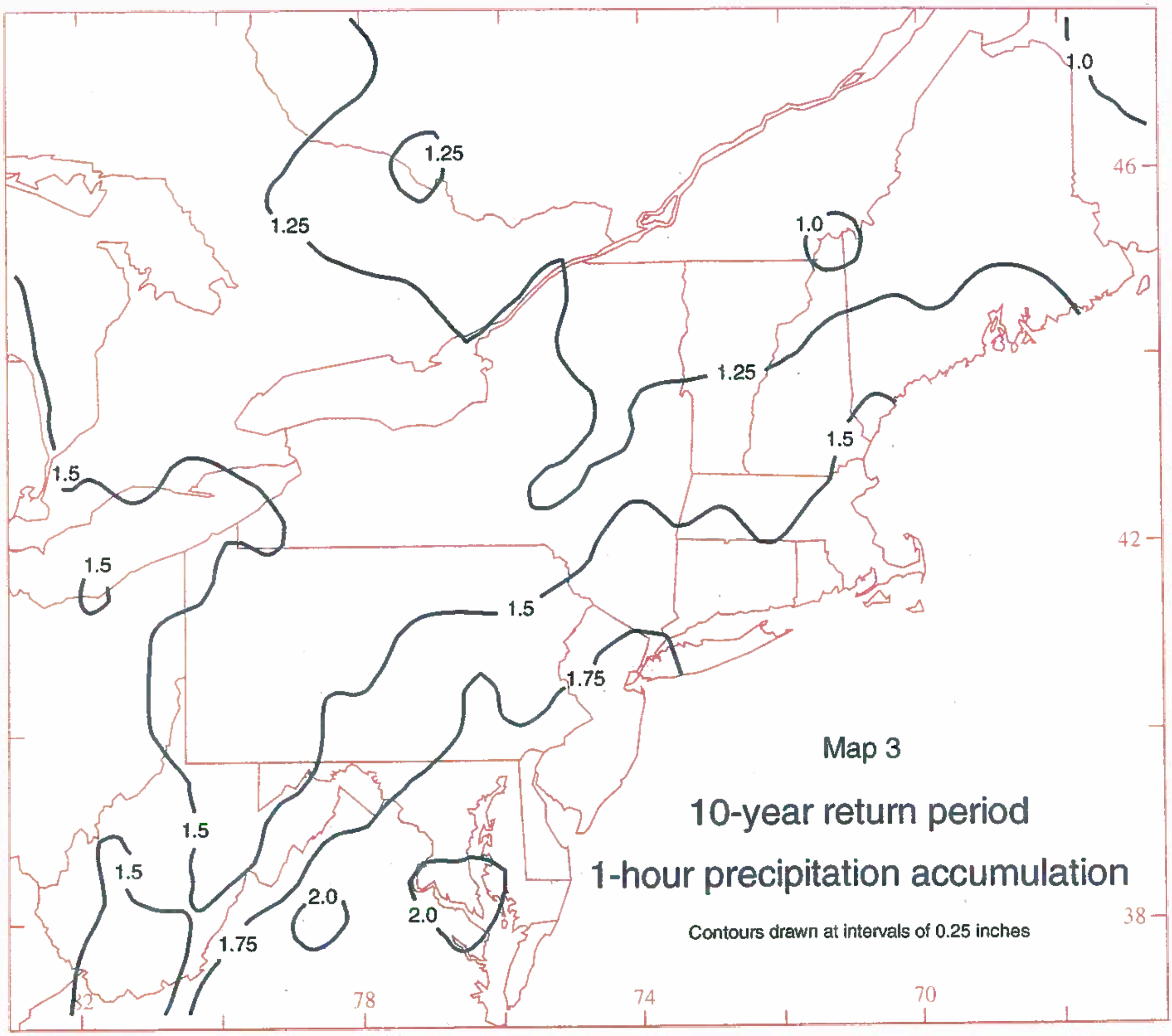
Cember, R.P., and D.S. Wilks, 1993. *Climatological Atlas of Snowfall and Snow Depth for the Northeastern United States and Southeastern Canada*. Northeast Regional Climate Center Research Publication RR 93-1, 216 pp.

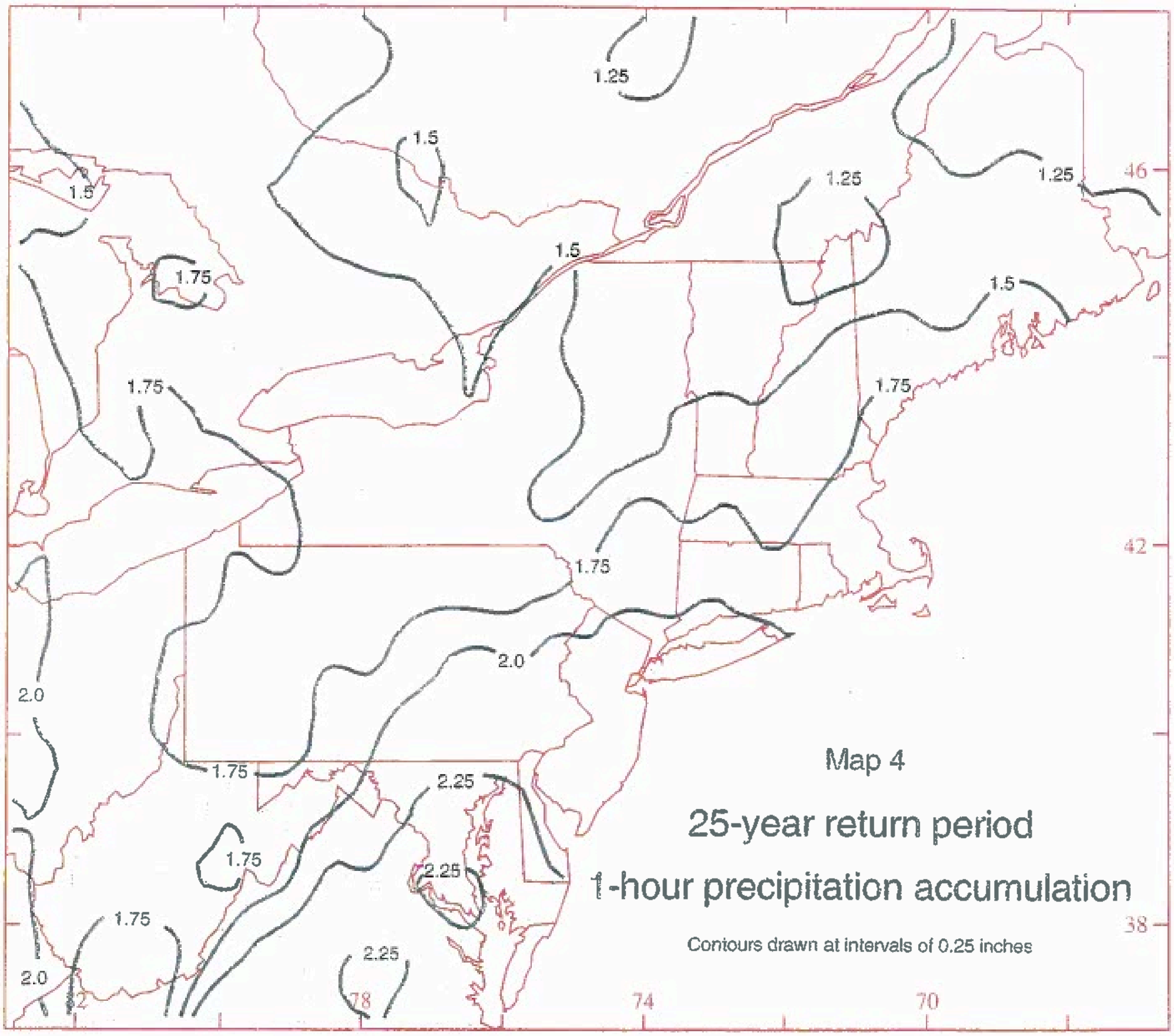
Huff, F.A., and J.R. Angel, 1992. *Rainfall Frequency Atlas of the Midwest*. Illinois State Water Survey, Champaign IL, Bulletin 71, 141 pp.

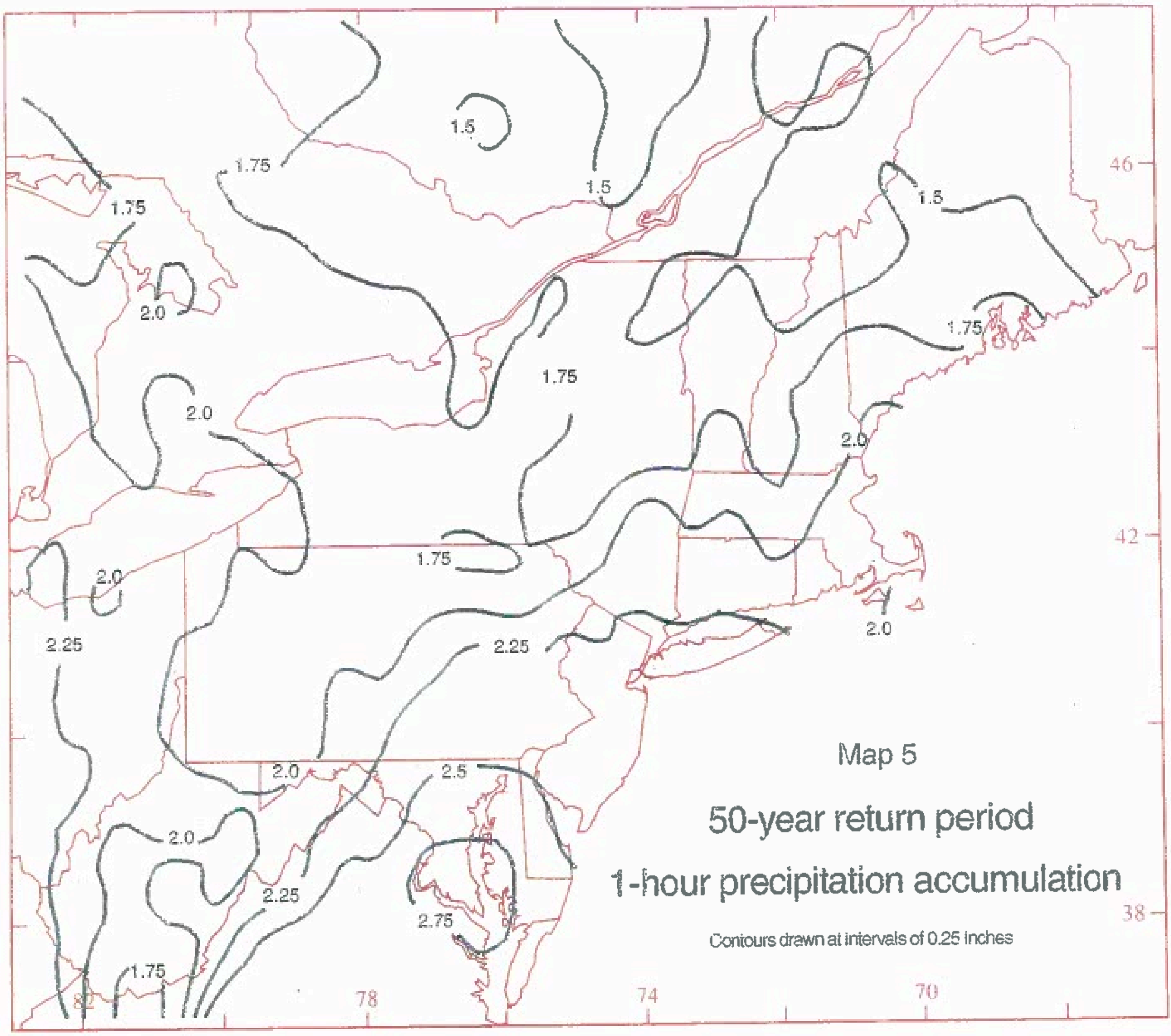

0.8
0.8
0.9
0.9
46
0.9
1.0
0.9
1.0
1.0
1.1
1.1
42
1.0
1.2
1.1
1.2
1.2
1.3
Map 1
2-year return period
1.1
1-hour precipitation accumulation
1.3
1.1
38
1.4
Contours drawn at intervals of 0.10 inches
82
78
74
70

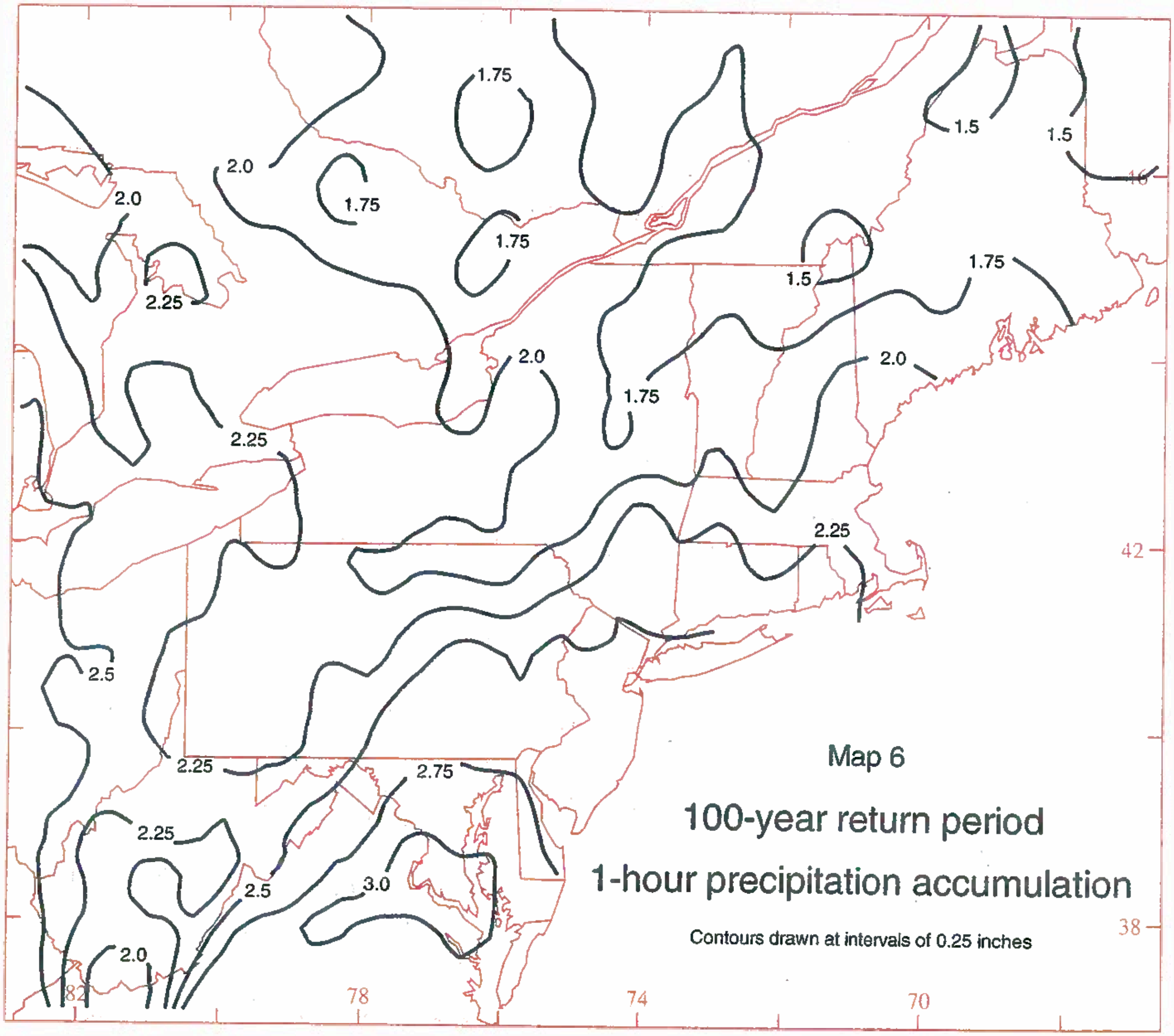


Map 2
5-year return period
1-hour precipitation accumulation
Contours drawn at intervals of 0.10 inches
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
46
42
38
82
78
74
70


Map 3
10-year return period
1-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches
1.0
1.25
1.5
1.75
2.0
46
42
38
78
74
70


Map 4
25-year return period
1-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches
1.25
1.5
1.75
2.0
2.25
46
42
38
74
70
78


1.5
1.75
1.5
1.75
1.5
2.0
1.75
2.0
1.75
2.0
1.75
2.0
2.0
2.25
2.25
2.0
2.5
2.0
2.25
2.75
1.75
46
42
38
82
78
74
70
Map 5
50-year return period
1-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches

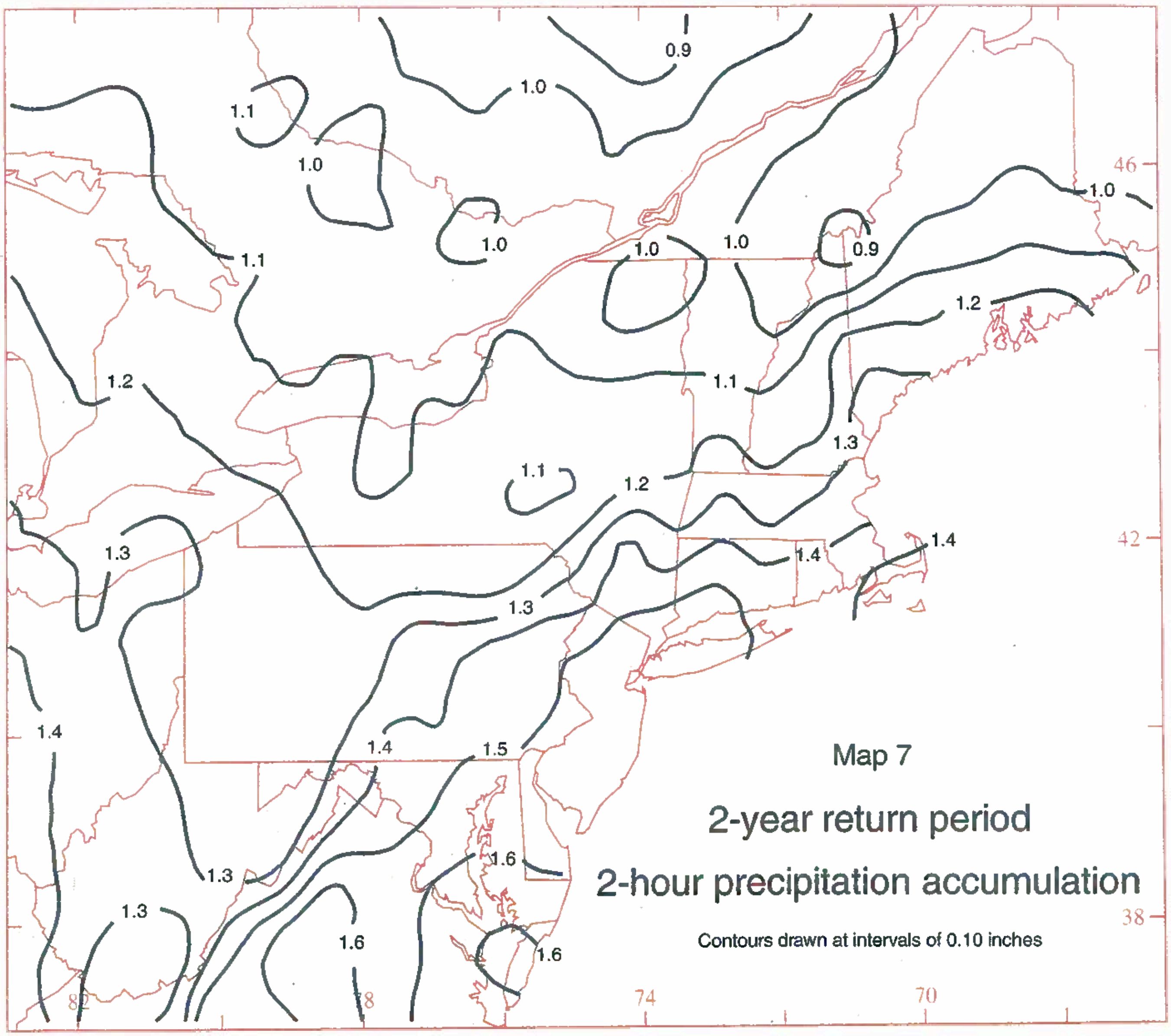


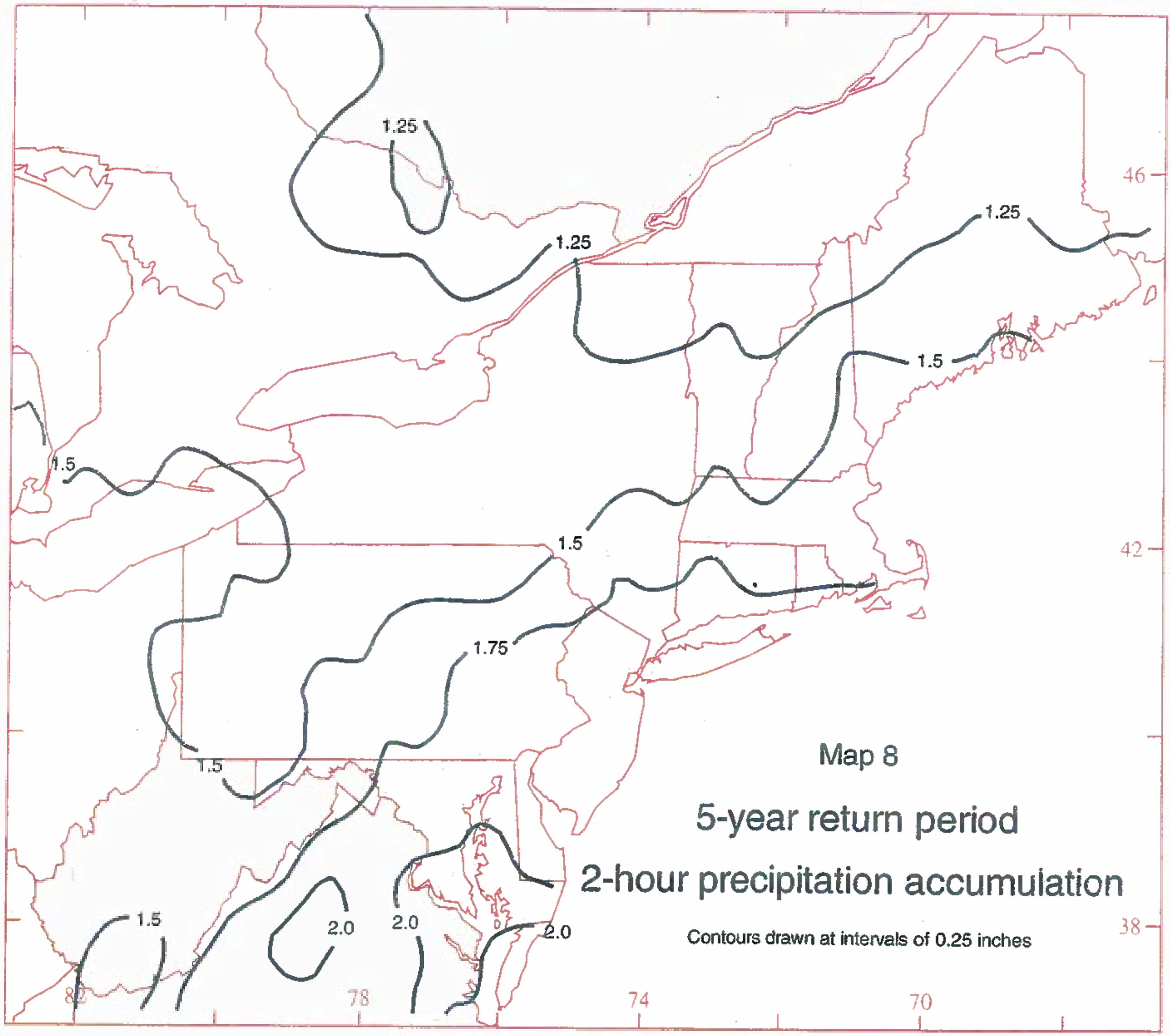
Map 6

100-year return period

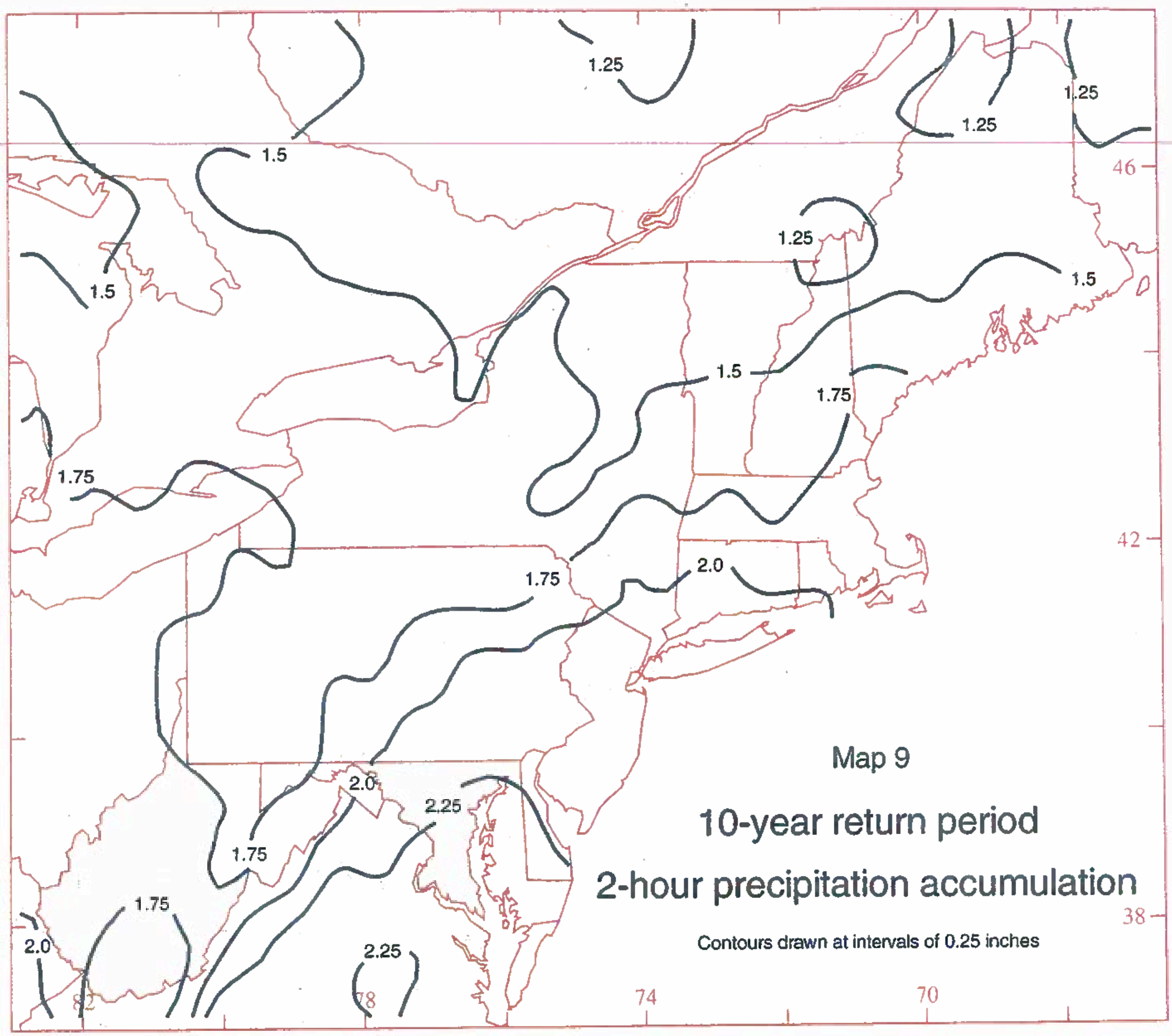
1-hour precipitation accumulation

Contours drawn at intervals of 0.25 inches


0.9
1.0
1.1
1.0
1.0
1.1
1.0
1.0
0.9
1.0
1.2
1.2
1.1
1.3
1.1
1.2
1.3
1.4
1.4
1.3
1.4
1.4
1.5
1.3
1.6
1.3
1.6
1.6
46
42
38
74
70
Map 7
2-year return period
2-hour precipitation accumulation
Contours drawn at intervals of 0.10 inches



Map 8
5-year return period
2-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches
1.25
1.25
1.25
1.5
1.5
1.5
1.5
1.5
1.75
2.0
2.0
2.0
46
42
38
82
78
74
70


Map 9
10-year return period
2-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches
1.25
1.25
1.25
1.25
1.5
1.5
1.5
1.5
1.75
1.75
1.75
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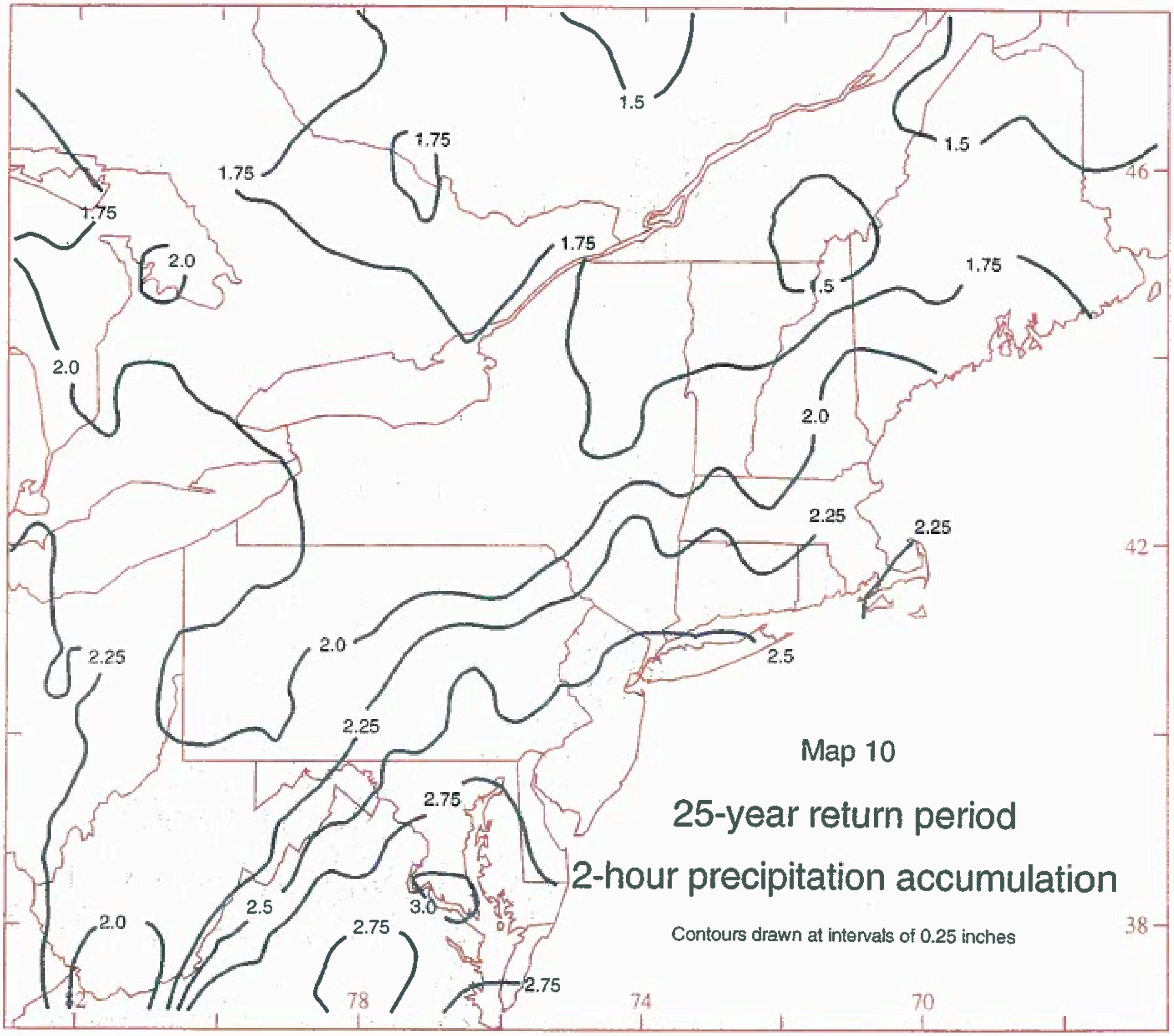
2.25
2.25
46
42
38
82
78
74
70

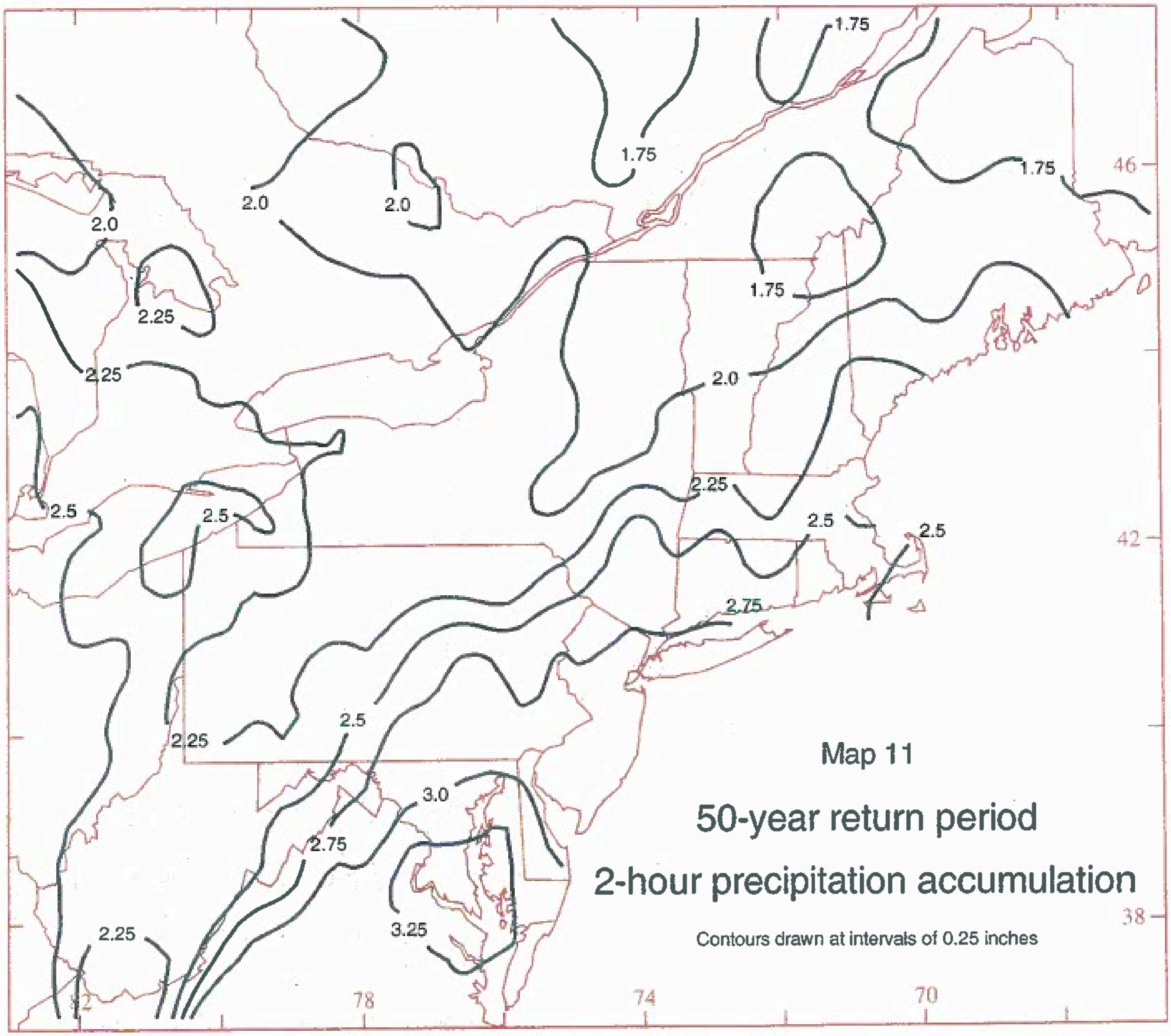


Map 10

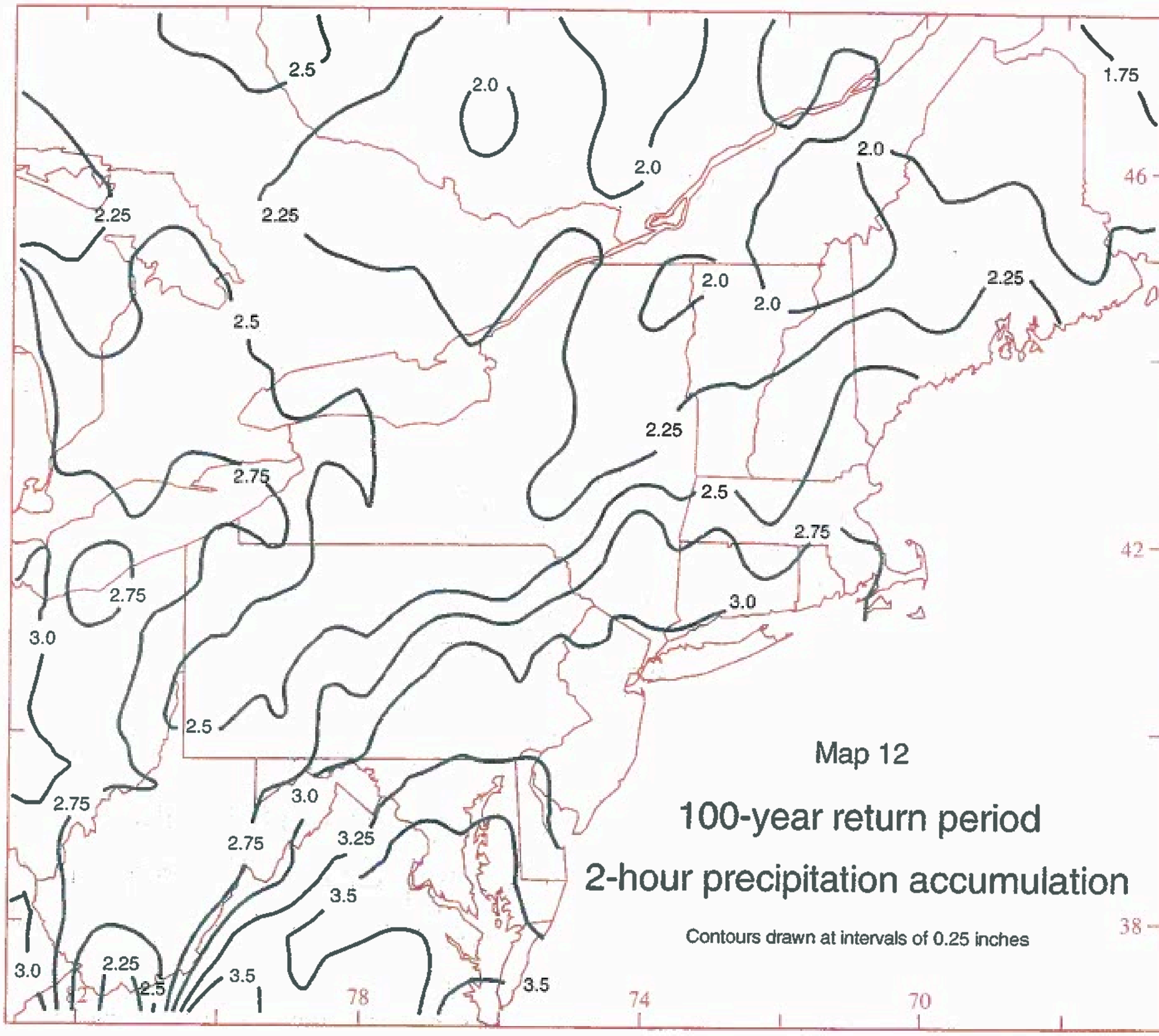
25-year return period

2-hour precipitation accumulation

Contours drawn at intervals of 0.25 inches



1.75
1.75
1.75
2.0
2.0
2.0
1.75
2.25
2.25
2.0
2.25
2.5
2.5
2.5
2.5
2.75
2.25
2.5
3.0
2.75
2.25
3.25
46
42
38
78
74
70
Map 11
50-year return period
2-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches

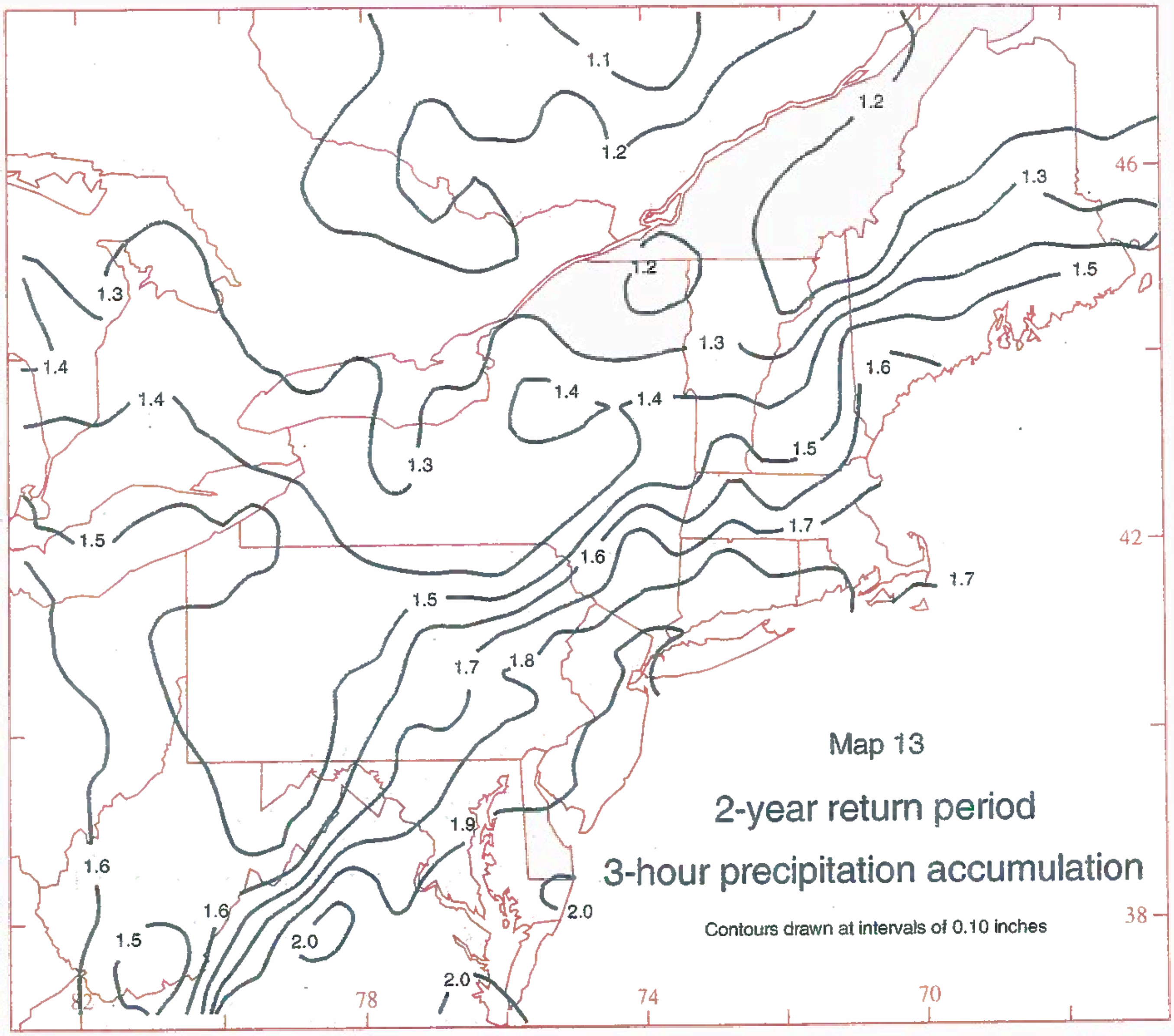


Map 12

100-year return period

2-hour precipitation accumulation

Contours drawn at intervals of 0.25 inches


Map 13
2-year return period
3-hour precipitation accumulation
Contours drawn at intervals of 0.10 inches
1.1
1.2
1.2
1.2
1.3
1.3
1.3
1.3
1.4
1.4
1.4
1.4
1.5
1.5
1.5
1.5
1.5
1.6
1.6
1.6
1.6
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38
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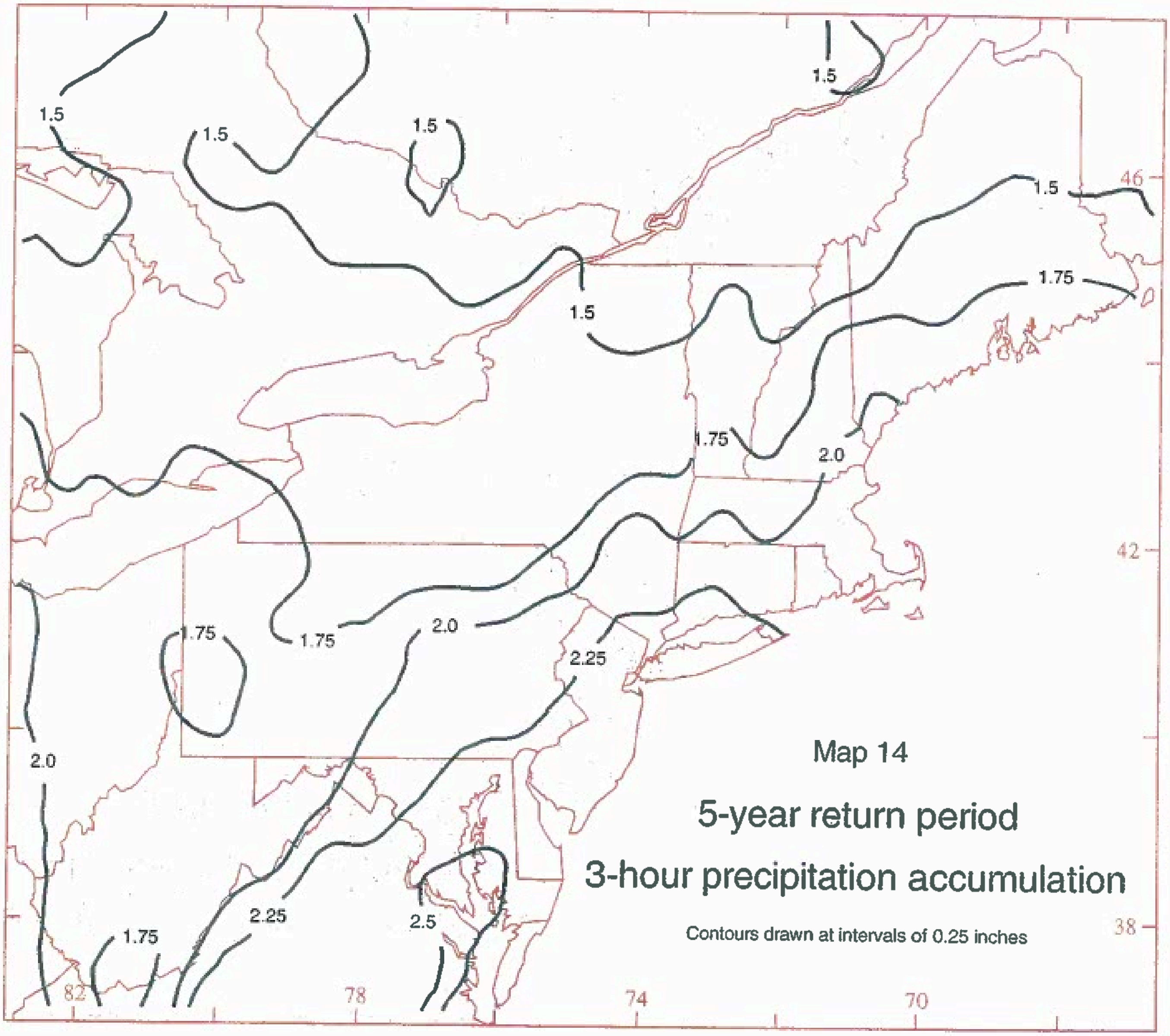
70

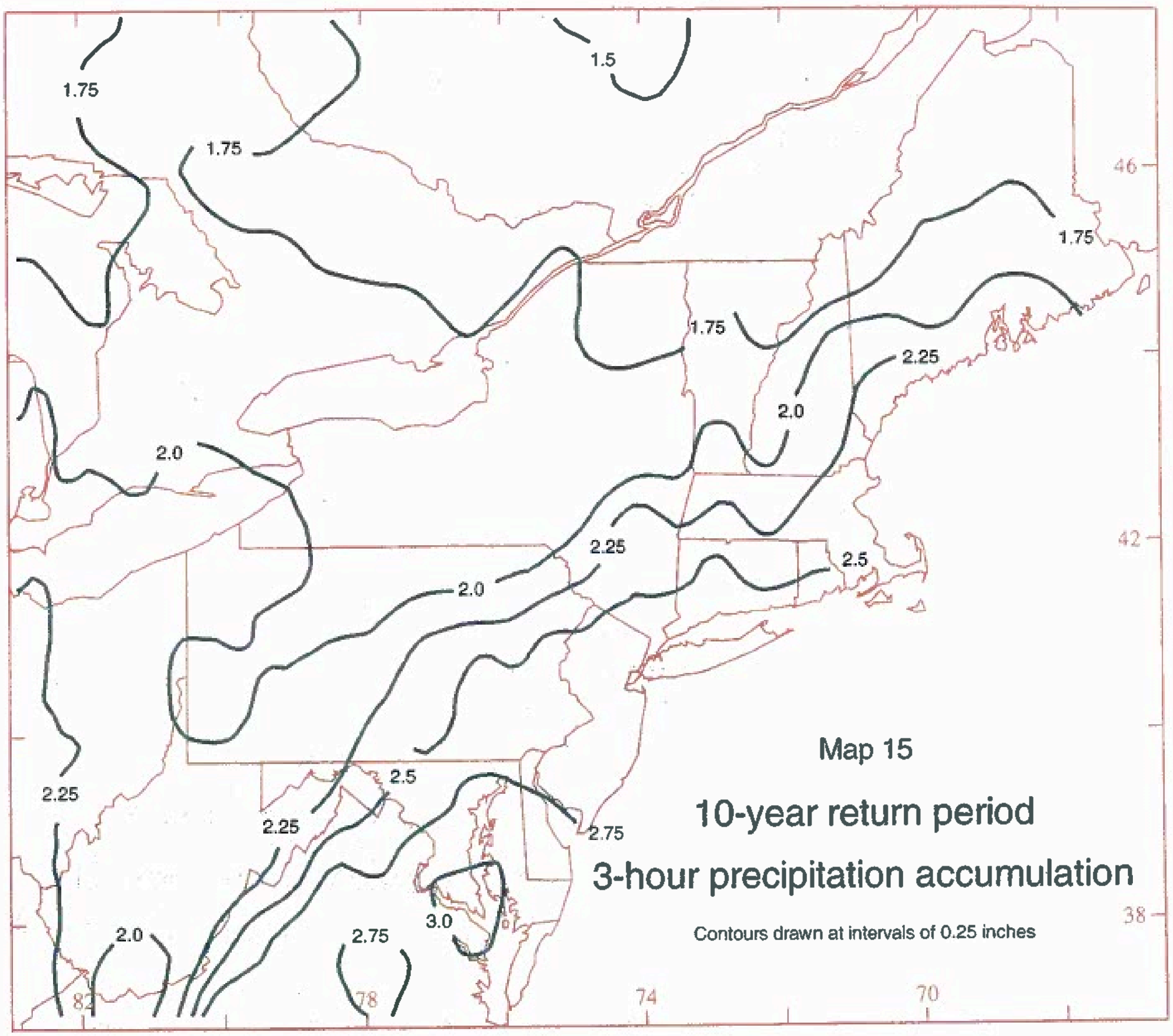


Map 14

5-year return period

3-hour precipitation accumulation

Contours drawn at intervals of 0.25 inches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1.75
1.5
46
1.75
1.75
2.25
2.0
2.0
42
2.25
2.0
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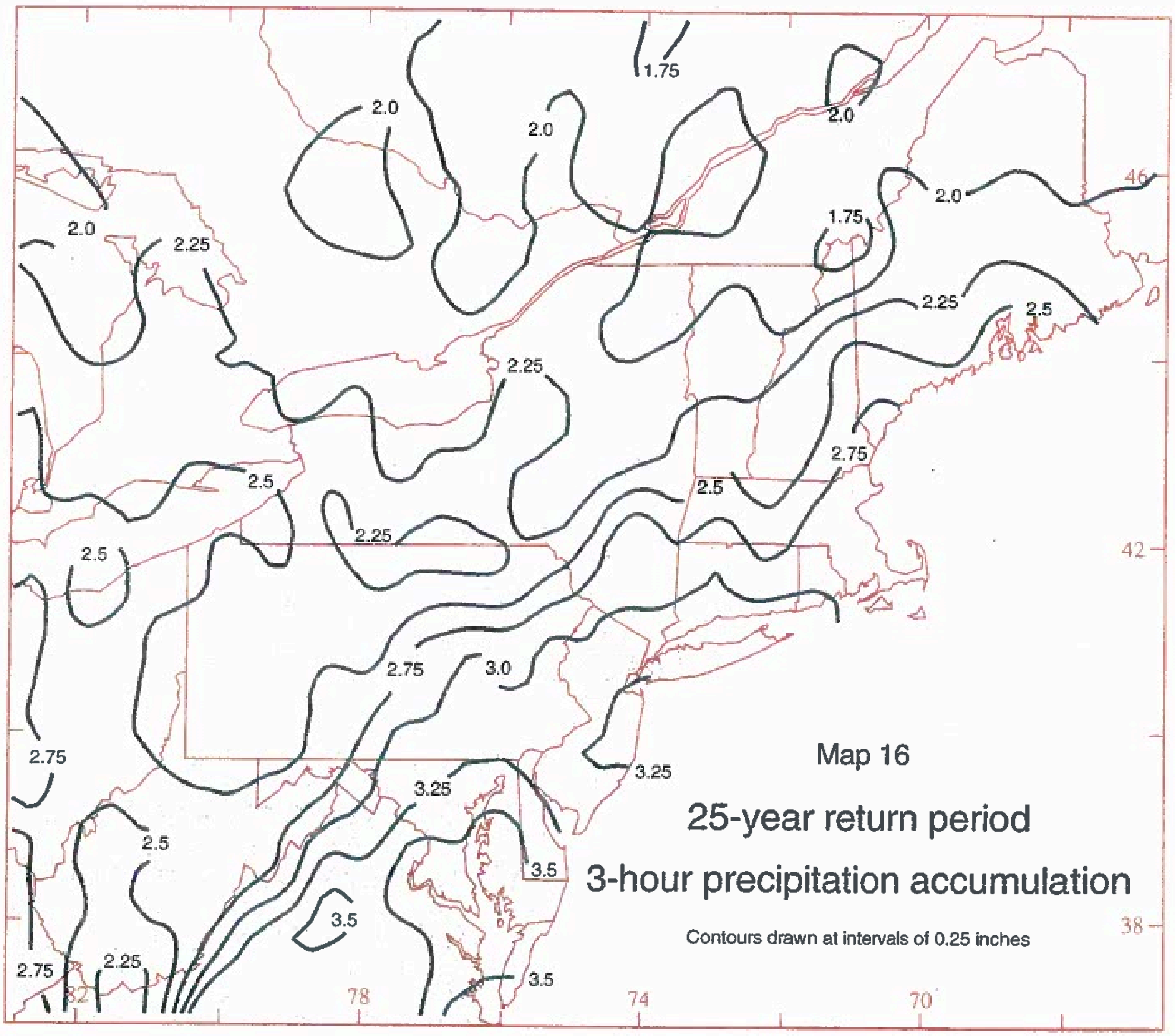
2.25
2.5
2.25
2.75
3.0
38
2.0
2.75
82
78
74
70
Map 15
10-year return period
3-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches



Map 16
25-year return period
3-hour precipitation accumulation
Contours drawn at intervals of 0.25 inches
1.75
2.0
2.25
2.5
2.75
3.0
3.25
3.5
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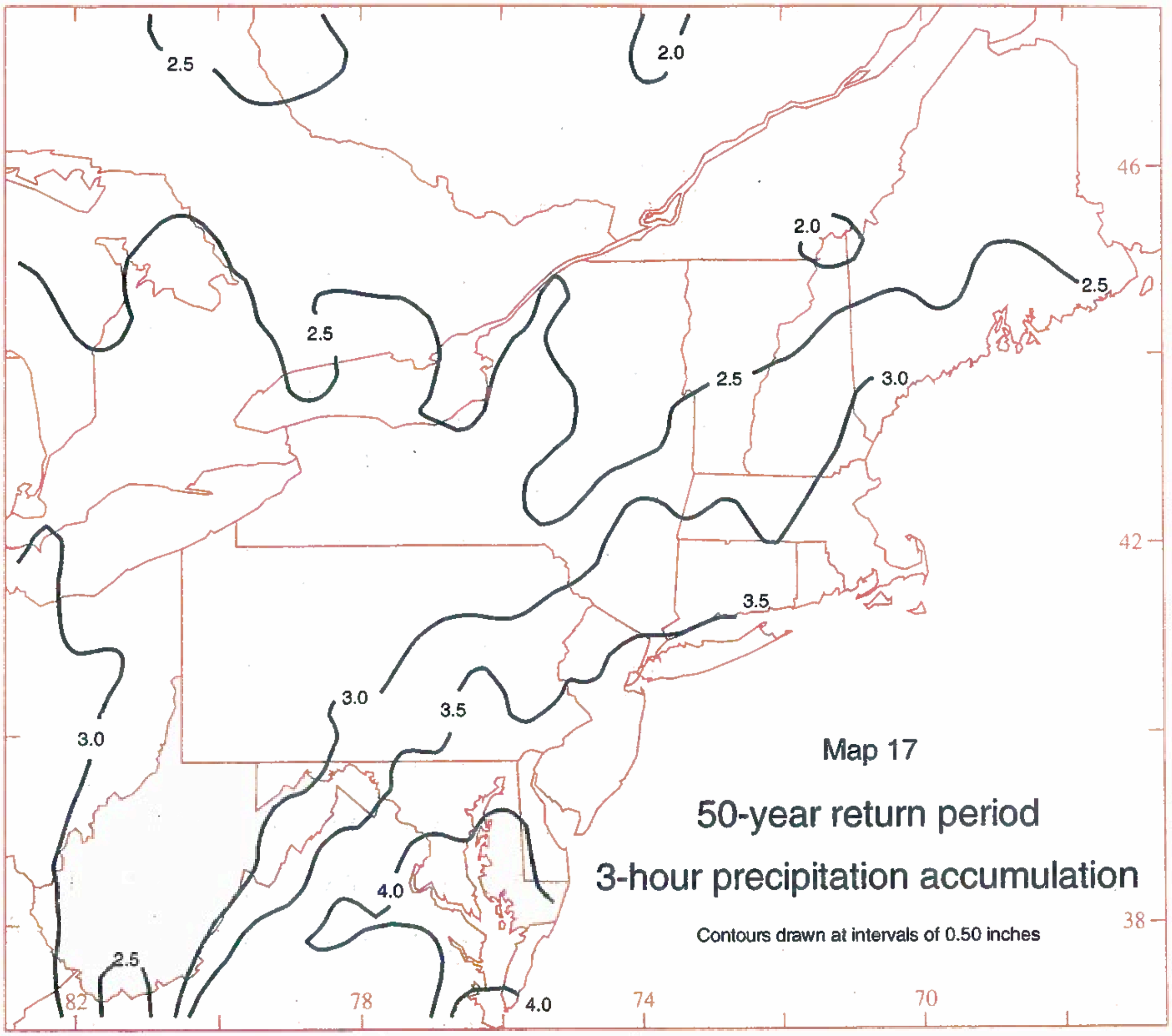
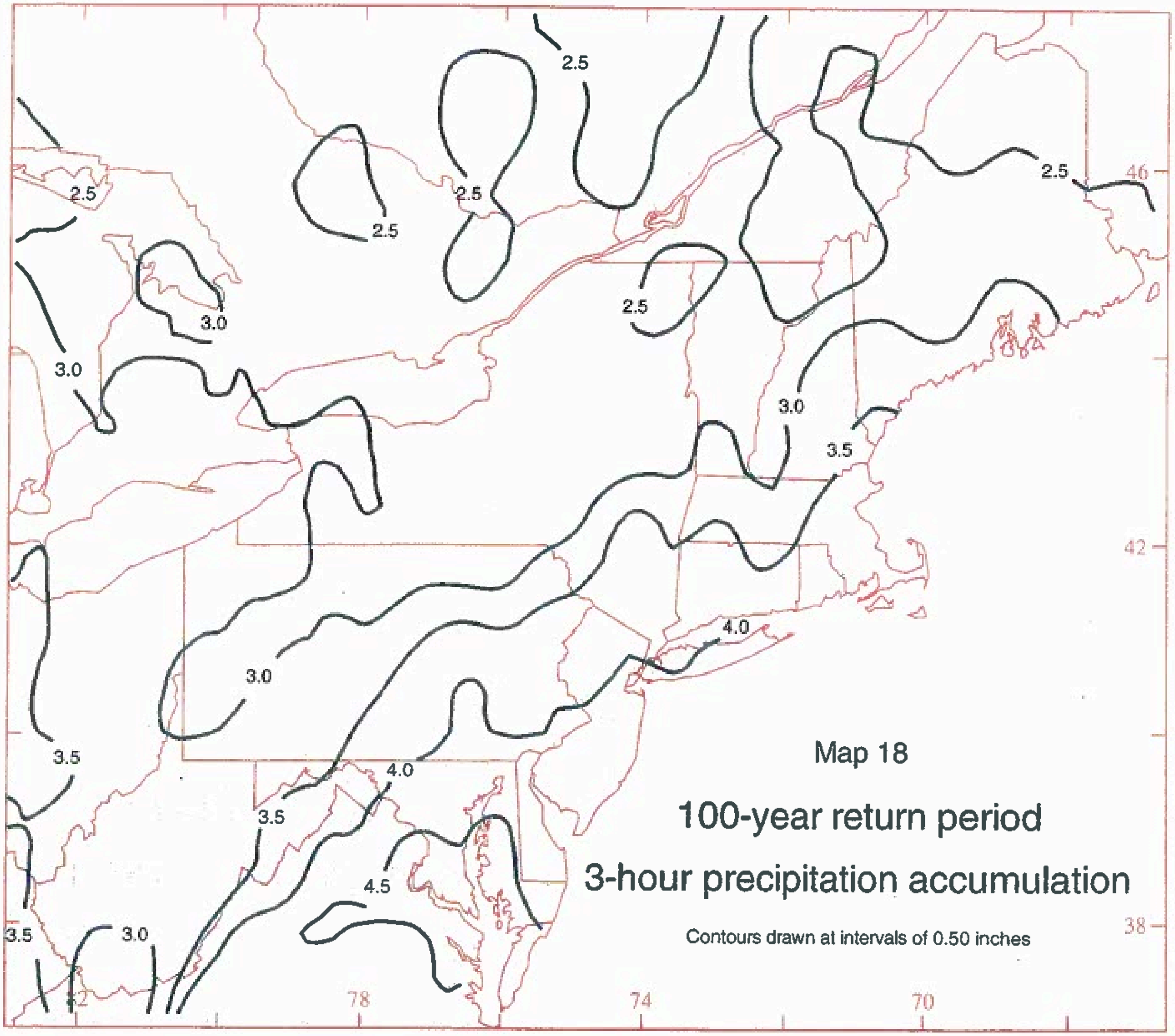
42
38
82
78
74
70


2.5
2.0
46
2.0
2.5
2.5
2.5
3.0
42
3.5
3.0
3.5
3.0
Map 17
50-year return period
3-hour precipitation accumulation
4.0
Contours drawn at intervals of 0.50 inches
38
2.5
82
78
4.0
74
70


2.5
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4.0
4.0
4.5
3.0
46
42
38
78
74
70
Map 18
100-year return period
3-hour precipitation accumulation
Contours drawn at intervals of 0.50 inches

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