# COMMENTS ON DESIGN OF EVAPORATION NETWORKS

by

Eugene L. Peck and John C. Monro

Hydrologic Research Laboratory
National Weather Service
National Oceanic and Atmospheric Administration
Silver Spring, Md. 20910

For presentation at International Seminar on Hydrological Network Design and Information Transfer, Newcastle-upon-Tyne, United Kingdom, 19-24 August 1974.

# Comments on Design of Evaporation Networks

Eugene L. Peck and John C. Monro*

## Introduction

In reviewing the literature of evaporation and evapotranspiration it is obvious that there are numerous papers reporting on the various methods of measuring evaporation and which attempt to relate such measurements to actual evapotranspiration (1) (2) (3) (4). There is, however, only a very limited number of references on the subject of the design of evaporation networks. It is evident that there is a considerable difference of opinion as to the most useful method of measuring or indexing evaporation. Also, a greater disparity exists as to the best method for relating measured evaporation to actual or potential evapotranspiration.

The most widely used method for estimating evaporation from lakes and reservoirs is to apply an appropriate coefficient to pan evaporation measurements. In the recent Casebook on Hydrological Network Design Practice, Hounam (5) discussed the general requirements for design of evaporation networks. He concluded that a network of pan or tank evaporimeters is a basic requirement but that this should be matched by a network of climatological stations as an aid to the development and evaluation of empirical formulae. These types of networks currently provide the measurements presently in use. Except for selected

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supplemental stations, the current state of the art precludes the practical measurement of actual evapotranspiration on a network basis.

## Network Requirements

Basic requirements for hydrologic network design are contained in the Casebook on Hydrological Network Design Practice, the proceedings of the Symposium on Design of Hydrological Networks held in Quebec, Canada, in June 1965, (6) and in the WMO/IHD Report on Hydrological Network Design Needs, Problems and Approaches (7). These publications point out that the spatial density of stations and the temporal reporting criteria should be determined by the user requirements of the data. For pan evaporation, there is a wide range of spatial density and temporal reporting requirements based on the user's needs. General water resources planning requires only monthly or seasonal evaporation averages. Reservoir operations probably utilize weekly information, while irrigation water users require almost daily evaporation input.

## Transferability of Pan Evaporation Data

A knowledge of the transferability (accuracy and information content) of pan evaporation data should serve as a guide to better understand the relationships needed for determining network design criteria. As a first step in this study, spatial correlation among pan evaporation data were investigated for monthly, 10-day, 5-day and daily average values. The Central Plains States of Nebraska and Kansas in the United States were selected as a study area. This area is relatively flat and contained a comparatively dense network of stations (37 current stations in approximately 400,000 square kilometers).

Maps of the cross correlation between a centrally located station, Harlan County Lake, Nebraska, and other stations in the two-state area are shown in Figures 1-4. The correlations for the monthly values indicate that a large section of the area has correlation values of 0.85 or greater. Maps for 10-day periods show a general decrease of about 0.05 in the correlation values and little change from the 10-day periods to 5-day periods. The map for the daily period shows a much greater gradient in the correlation lines. Correlation decay was apparently related to direction (interstation bearings) however; no definite physical explanation is apparent for this observation. A tentative conclusion might be that general climatic changes across the area of study, combined with prevailing wind directions and site peculiarities contribute to this effect.

Plots of correlation with distance were also prepared for Harlan County Lake versus all stations in the area for each of the four periods 30-day, 10-day, 5-day and one day, Figures 5-8.

The curves for all stations indicated that the general relation between correlation and distance is linear. In addition, inter-station distance, time interval, seasonal variation, and gage site exposure should all be considered when defining the transferability of pan evaporation data.

In studies of variability of evaporation in mountainous area, Peck (8) observed that the relation of evaporation among different sites was dependent upon the exposure of the evaporation measurement locations. Boohin (9) stated that an open site with free wind movement in the area of the pan was a criteria for a suitable exposure. Sites with obstructed exposures should not have the same relations among stations as those with open sites. This was found to be true for the daily relations shown in Figure 8. Correlation decreases more rapidly with distance from the site for those pans having obstructed exposure. Obstructed exposure in this study was assigned if vegetation blocked the wind movement within 100 yards in more than two cardinal directions and/or a major geography feature such as a large bluff prevented free wind movement from all directions.

Figure 9 shows a comparison of the curves for the four periods. Figure 10 is a composite of the various graphs relating the change in correlation with distances versus the time interval in days.

Seasonal variation in the cross correlation between Harlan County Lake and all other stations was investigated for daily pan values. Figure 11 summarizes the results. An in-depth interpretation of this seasonal variation will require additional analysis. However, the following is suggested:

a. seasonal variability seems sufficiently important to be incorporated into a network design.

b. correlation is significantly greater for high evaporation months than for low evaporation months at distances up to 125 km.

The applicability of the transfer of pan data depends on what use is made of the information. Information content of a particular network can be related inversely to the variance of the statistical estimate of the pan data. Conversely the accuracy of a particular network in terms of defining point values is related directly to the variance of the statistical estimate. Table 1 summarizes the accuracy of predicting pan evaporation from Harlan County Lake both in terms of distance from this site and the time interval of the data.

Table 1

| Distance (km) from Harlan County Lake, Nebraska | Explained Variance ($\hat{r}^2$) | | | |
|---|---|---|---|---|
| | 30-day | 10-day | 5-day | 1-day |
| 50 | .88 | .85 | .88 | .65 |
| 100 | .85 | .79 | .80 | .55 |
| 200 | .79 | .67 | .65 | .37 |
| 400 | .68 | .47 | .39 | .13 |

## Future Work

The Office of Hydrology of the National Weather Service is primarily responsible for the basic hydrometeorological networks in the United States including evaporation. This office also has the mission of issuing river and flood forecasts for the country. A major potential use of evaporation data is as an indicator of evapotranspiration over a river basin and used as an input to conceptual modeling for river forecasting (10). The adequacy of the national network should therefore be judged in terms of its influence on the forecasting of river through the use of the conceptual models.

The information on evaporation data transferability must be used in conjunction with the models used in river forecasting, thereby considering the catchment dynamics. This approach would be somewhat analogous to the concept described by Eaglesen (11) in defining an optimum density of rainfall stations appropriate for a given rainfall - runoff relationship. In addition, consideration should be given to the use of other approaches to estimating evapotranspiration in conceptual modeling either as a substitute or in combination with observed pan data.

## References


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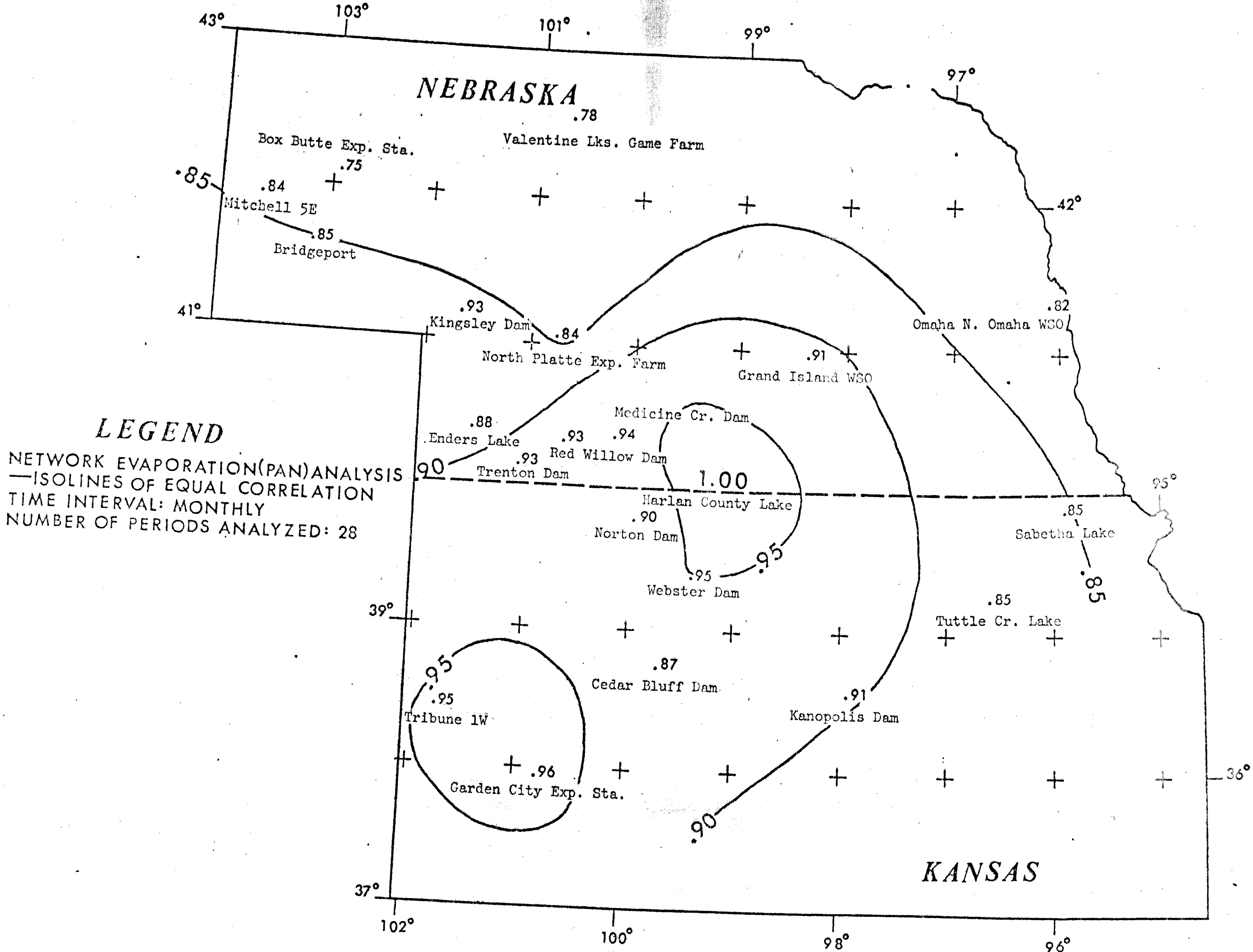
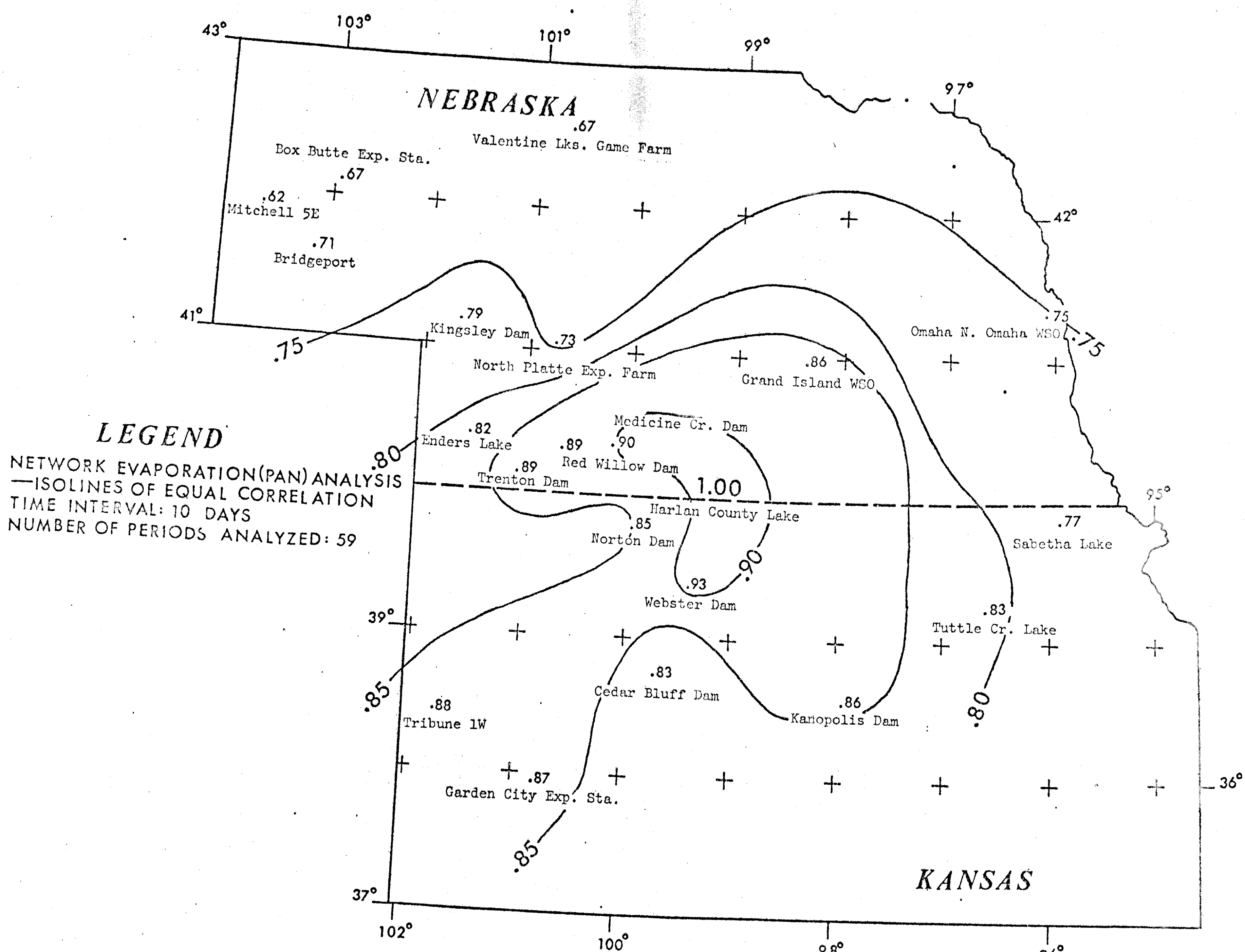


NEBRASKA
KANSAS
LEGEND
NETWORK EVAPORATION(PAN)ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: MONTHLY
NUMBER OF PERIODS ANALYZED: 28
43°
103°
101°
99°
97°
42°
41°
39°
37°
95°
36°
102°
100°
98°
96°
.78 Valentine Lks. Game Farm
Box Butte Exp. Sta. .75
.84 Mitchell 5E
.85 Bridgeport
.93 Kingsley Dam
.84 North Platte Exp. Farm
.91 Grand Island WSO
.82 Omaha N. Omaha WSO
.88 Enders Lake
.93 Red Willow Dam
.94 Medicine Cr. Dam
.93 Trenton Dam
1.00 Harlan County Lake
.90 Norton Dam
.95 Webster Dam
.85 Sabetha Lake
.85 Tuttle Cr. Lake
.87 Cedar Bluff Dam
.91 Kanopolis Dam
.95 Tribune 1W
.96 Garden City Exp. Sta.
.85
.90
.95

Figure 1.



NEBRASKA
KANSAS
43°
103°
101°
99°
97°
42°
41°
39°
37°
36°
95°
102°
100°
98°
96°
.67
Valentine Lks. Game Farm
Box Butte Exp. Sta.
.67
.62
Mitchell 5E
.71
Bridgeport
.79
Kingsley Dam
.73
North Platte Exp. Farm
.75
Omaha N. Omaha WSO
.75
.86
Grand Island WSO
.82
Enders Lake
.89
.90
Medicine Cr. Dam
Red Willow Dam
.89
Trenton Dam
1.00
Harlan County Lake
.85
Norton Dam
.90
.93
Webster Dam
.77
Sabetha Lake
.83
Tuttle Cr. Lake
.80
.80
.85
.88
Tribune 1W
.83
Cedar Bluff Dam
.86
Kanopolis Dam
.87
Garden City Exp. Sta.
.85
.75
LEGEND
NETWORK EVAPORATION(PAN) ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: 10 DAYS
NUMBER OF PERIODS ANALYZED: 59


Figure 2.

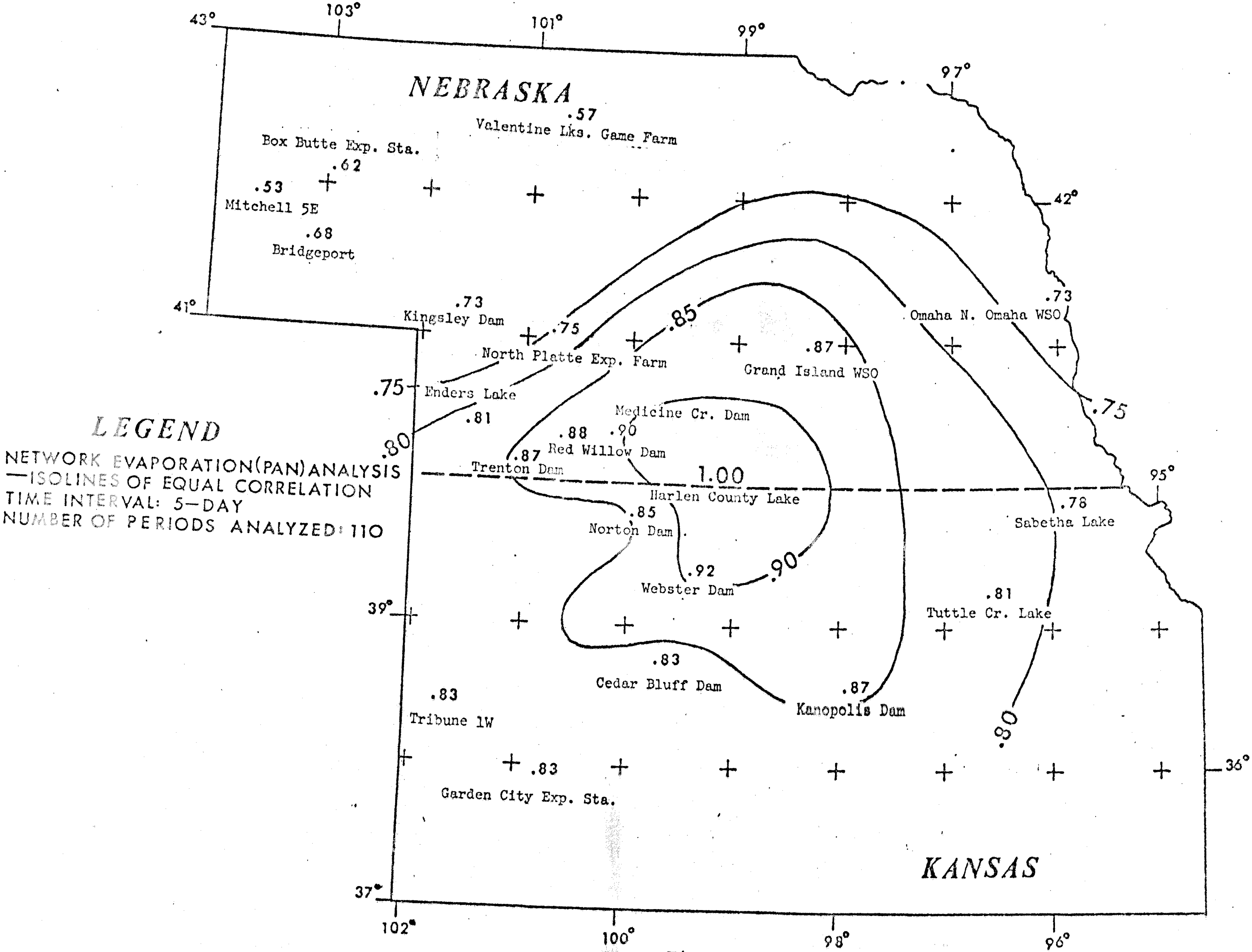

NEBRASKA
KANSAS
.57 Valentine Lks. Game Farm
Box Butte Exp. Sta. .62
.53 Mitchell 5E
.68 Bridgeport
.73 Kingsley Dam
.75 North Platte Exp. Farm
Enders Lake .81
.87 Grand Island WSO
Omaha N. Omaha WSO .73
Medicine Cr. Dam
.88 .90 Red Willow Dam
.87 Trenton Dam
1.00
Harlen County Lake
.85 Norton Dam
.92 Webster Dam
.78 Sabetha Lake
.81 Tuttle Cr. Lake
.83 Cedar Bluff Dam
.87 Kanopolis Dam
.83 Tribune 1W
.83 Garden City Exp. Sta.
.75
.80
.85
.90
43°
103°
101°
99°
97°
42°
41°
95°
39°
36°
37°
102°
100°
98°
96°
LEGEND
NETWORK EVAPORATION(PAN)ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: 5-DAY
NUMBER OF PERIODS ANALYZED: 110

Figure 3.

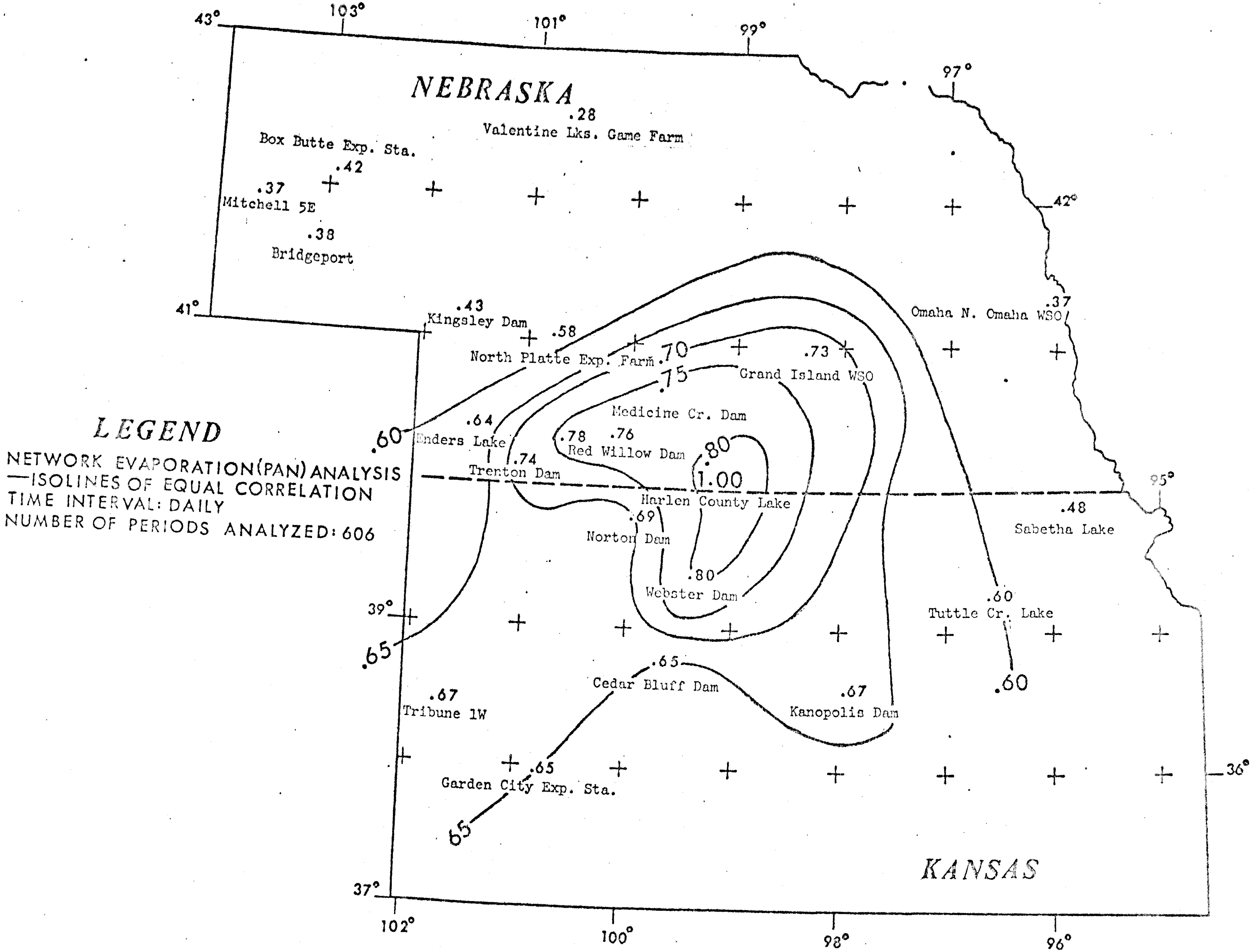

NEBRASKA
KANSAS
LEGEND
NETWORK EVAPORATION(PAN) ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: DAILY
NUMBER OF PERIODS ANALYZED: 606
43°
103°
101°
99°
97°
42°
41°
39°
37°
36°
95°
102°
100°
98°
96°
.28 Valentine Lks. Game Farm
Box Butte Exp. Sta. .42
.37 Mitchell 5E
.38 Bridgeport
.43 Kingsley Dam
.58 North Platte Exp. Farm
.64 Enders Lake
.74 Trenton Dam
.78 Red Willow Dam
.76
Medicine Cr. Dam
.73 Grand Island WSO
.37 Omaha N. Omaha WSO
Harlen County Lake
.69 Norton Dam
Webster Dam
.48 Sabetha Lake
.60 Tuttle Cr. Lake
.65 Cedar Bluff Dam
.67 Kanopolis Dam
.67 Tribune 1W
.65 Garden City Exp. Sta.
.60
.65
.70
.75
.80
1.00
.80
.60
65

Figure 4.

Figure 5. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

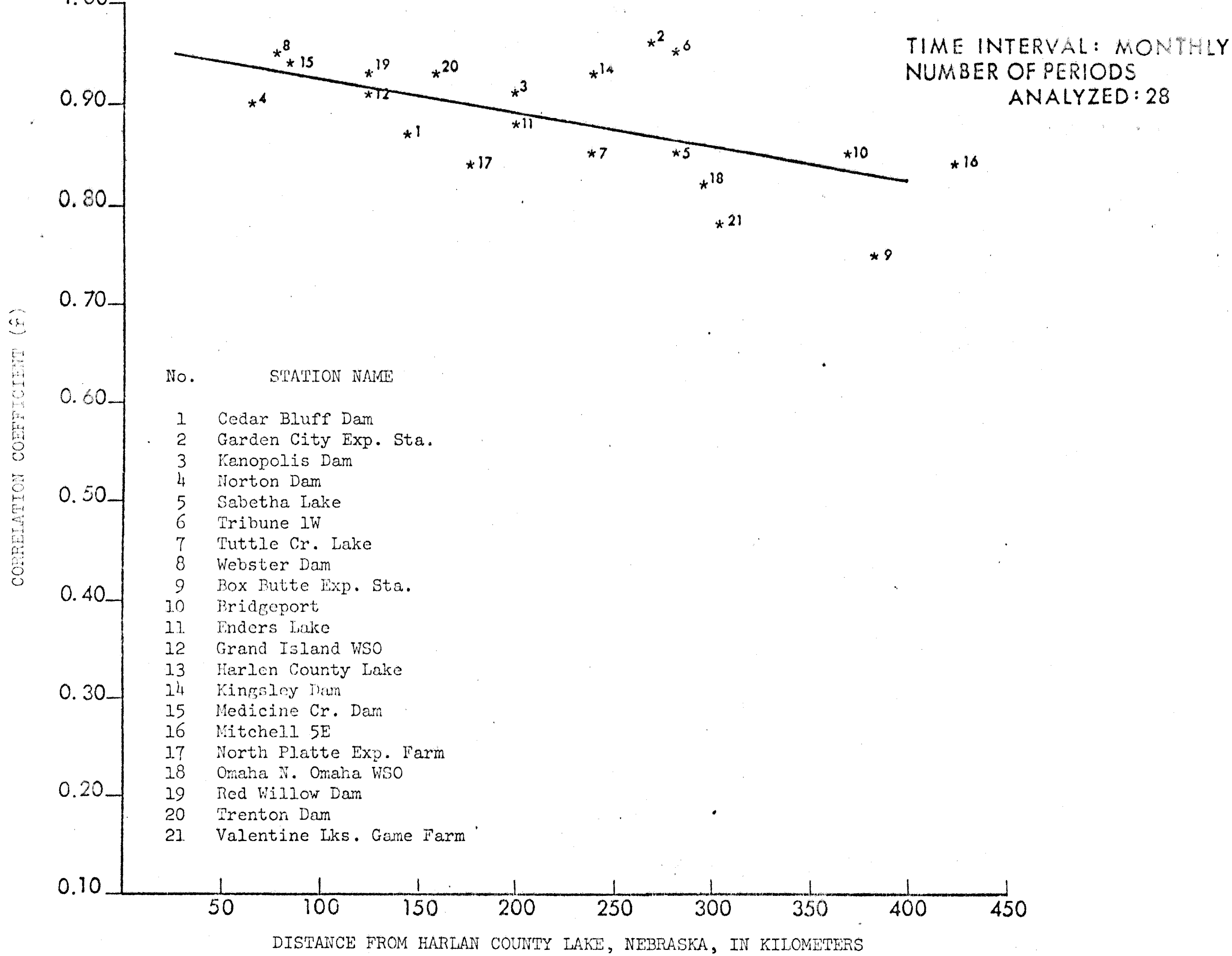


Figure 6. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

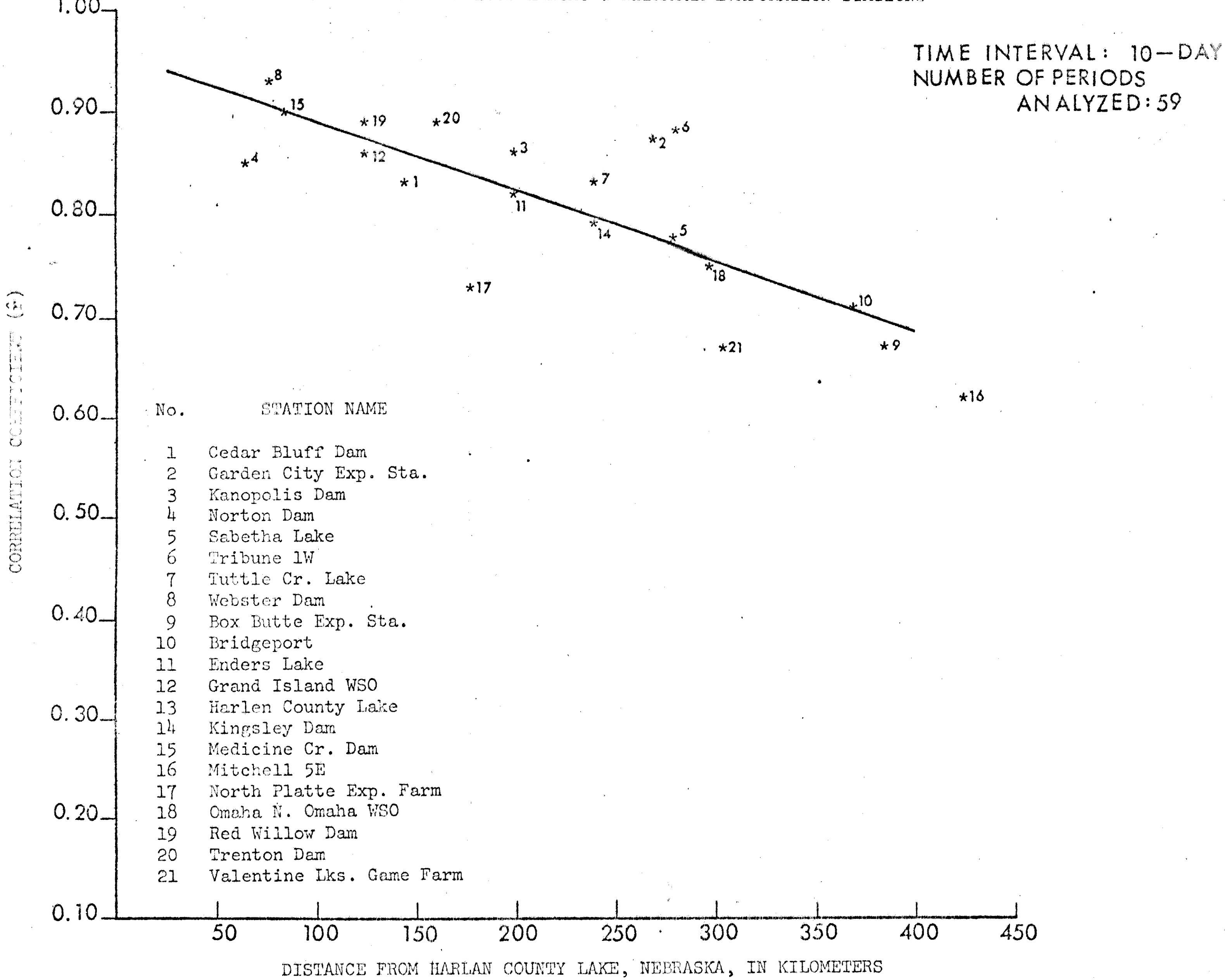
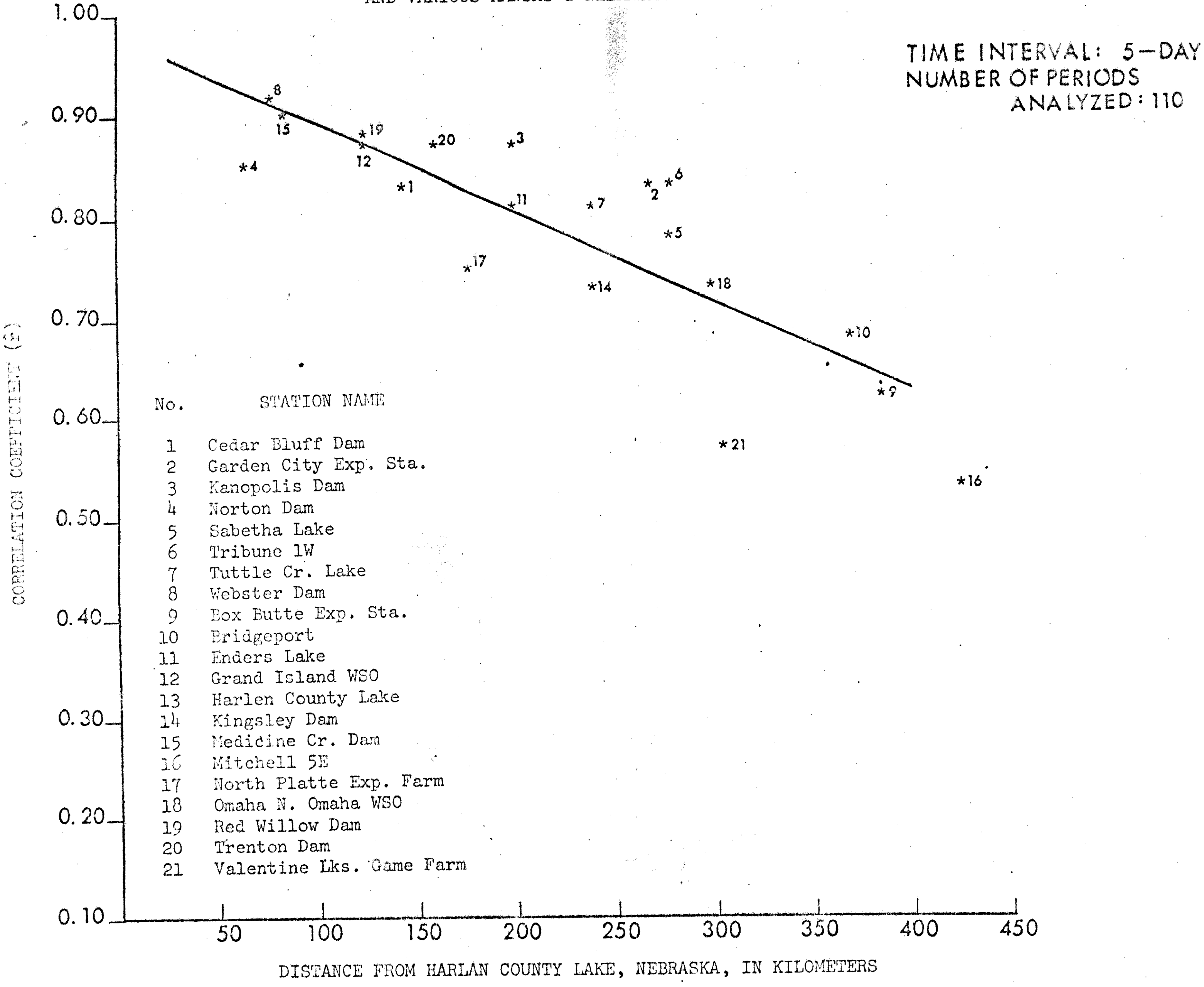


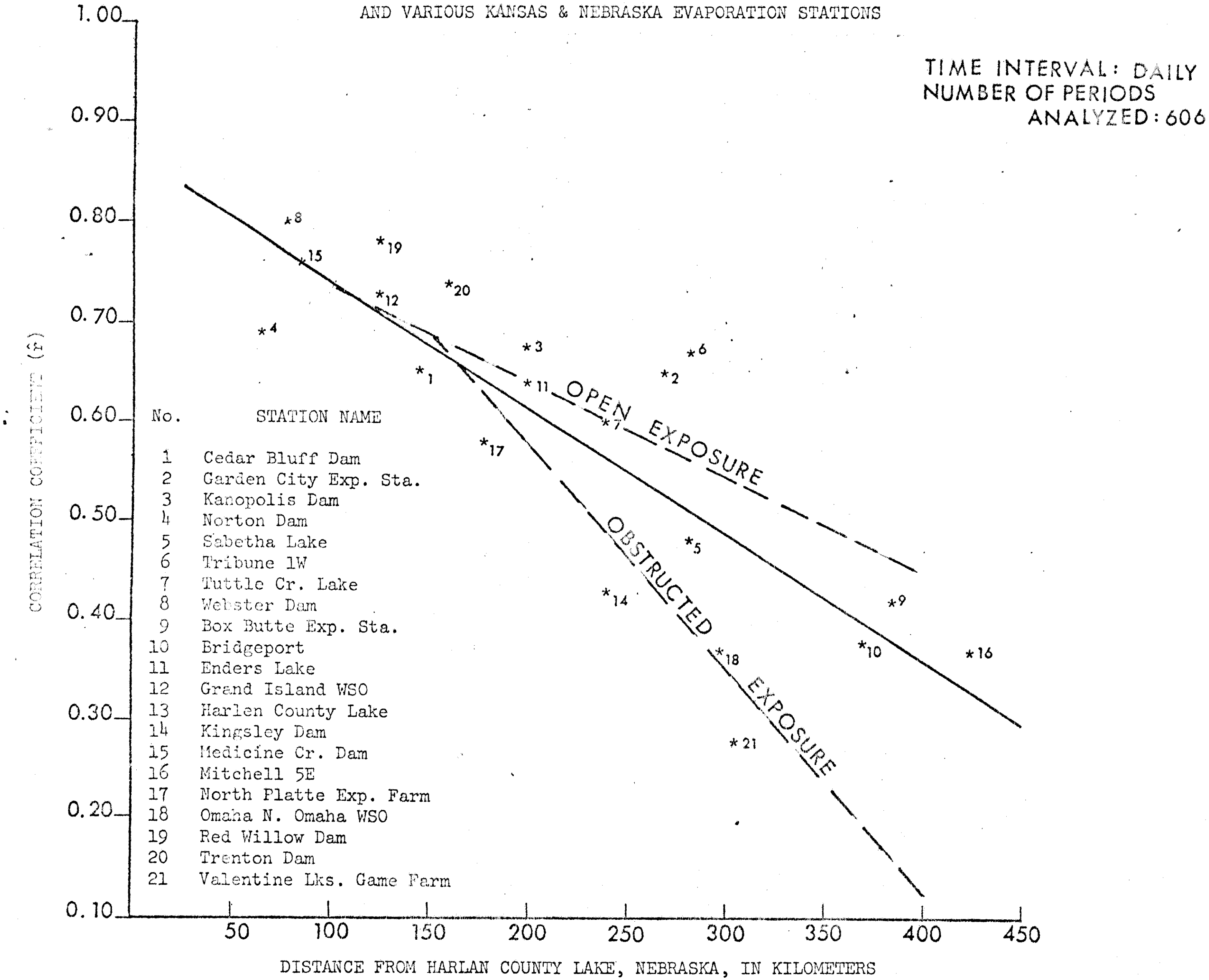
Figure 7. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS




| No. | STATION NAME |
|---|---|
| 1 | Cedar Bluff Dam |
| 2 | Garden City Exp. Sta. |
| 3 | Kanopolis Dam |
| 4 | Norton Dam |
| 5 | Sabetha Lake |
| 6 | Tribune 1W |
| 7 | Tuttle Cr. Lake |
| 8 | Webster Dam |
| 9 | Box Butte Exp. Sta. |
| 10 | Bridgeport |
| 11 | Enders Lake |
| 12 | Grand Island WSO |
| 13 | Harlen County Lake |
| 14 | Kingsley Dam |
| 15 | Medicine Cr. Dam |
| 16 | Mitchell 5E |
| 17 | North Platte Exp. Farm |
| 18 | Omaha N. Omaha WSO |
| 19 | Red Willow Dam |
| 20 | Trenton Dam |
| 21 | Valentine Lks. Game Farm |

Figure 8.

CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE
AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS



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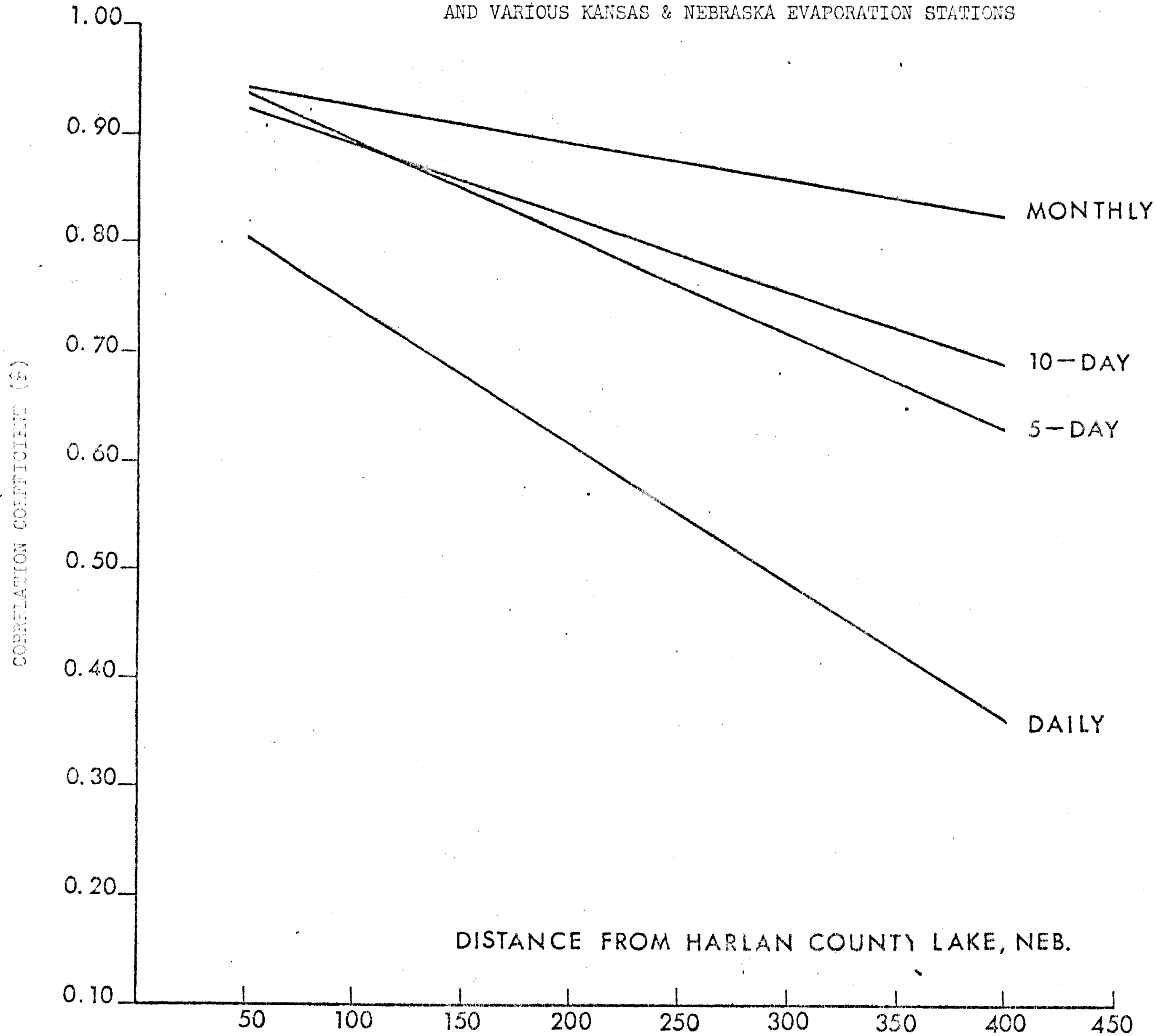


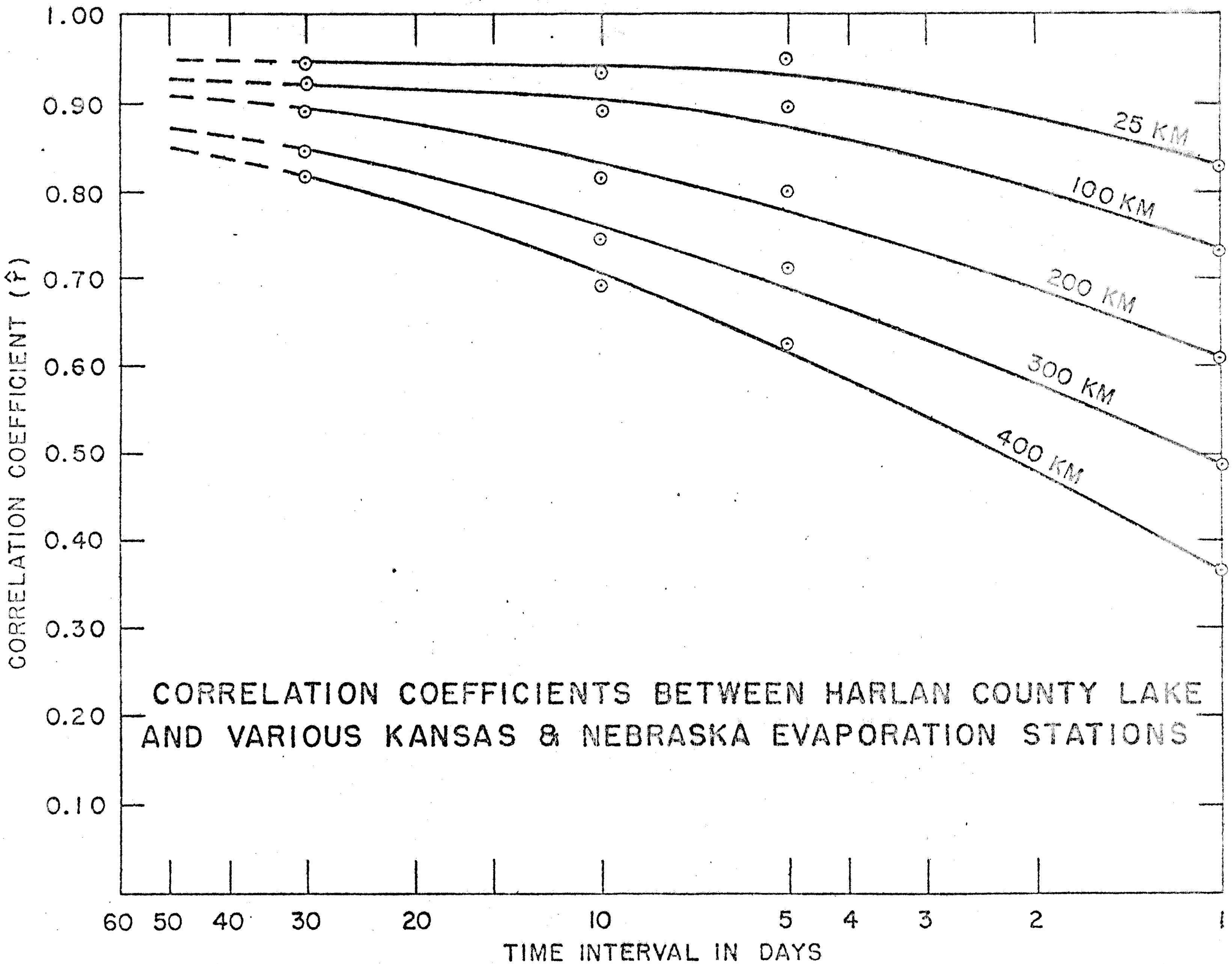
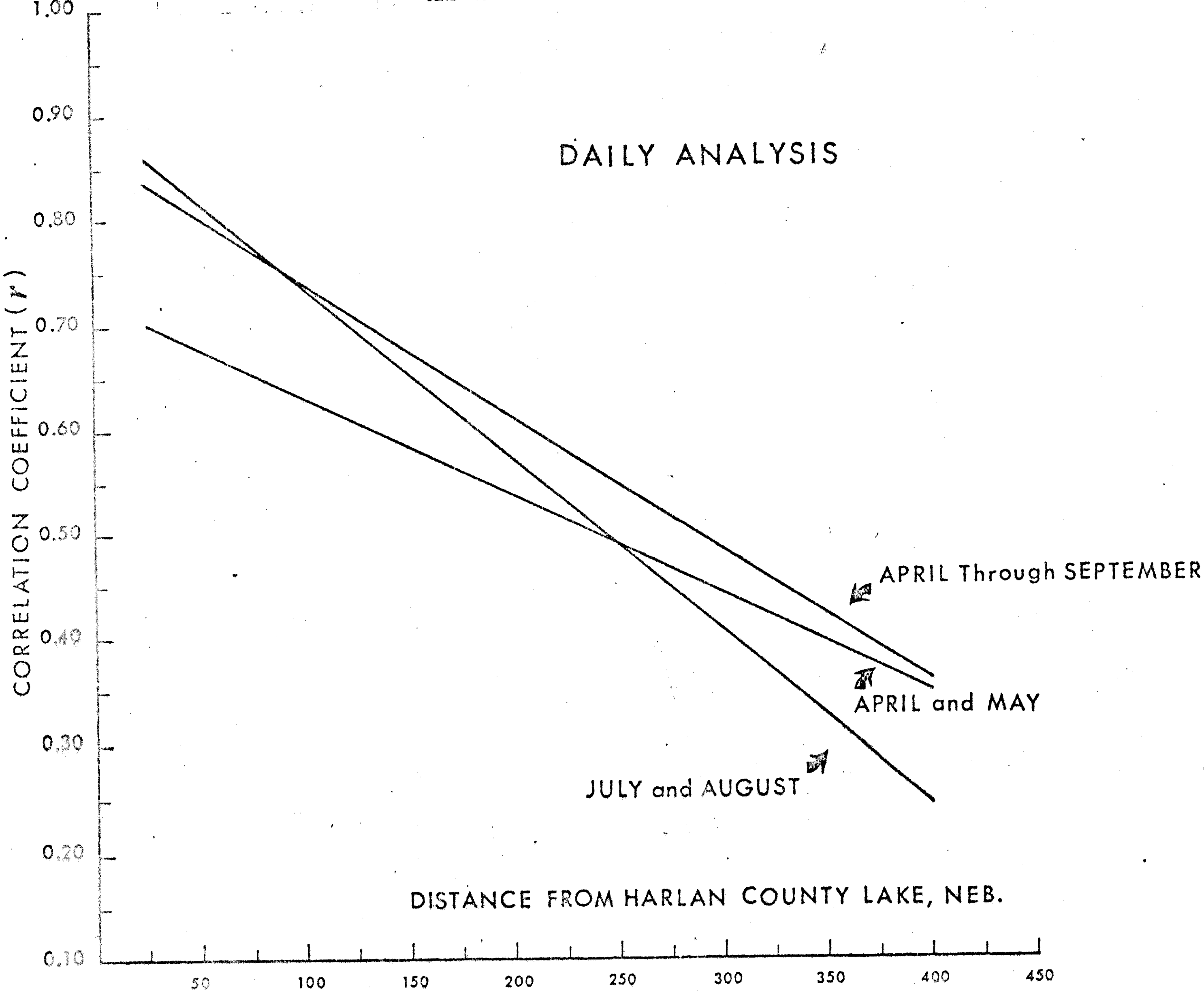

CORRELATION COEFFICIENT (r̂)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
25 KM
100 KM
200 KM
300 KM
400 KM
CORRELATION COEFFICIENTS BETWEEN HARLAN COUNTY LAKE
AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS
60
50
40
30
20
10
5
4
3
2
1
TIME INTERVAL IN DAYS

Figure 10.

Figure 11. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS



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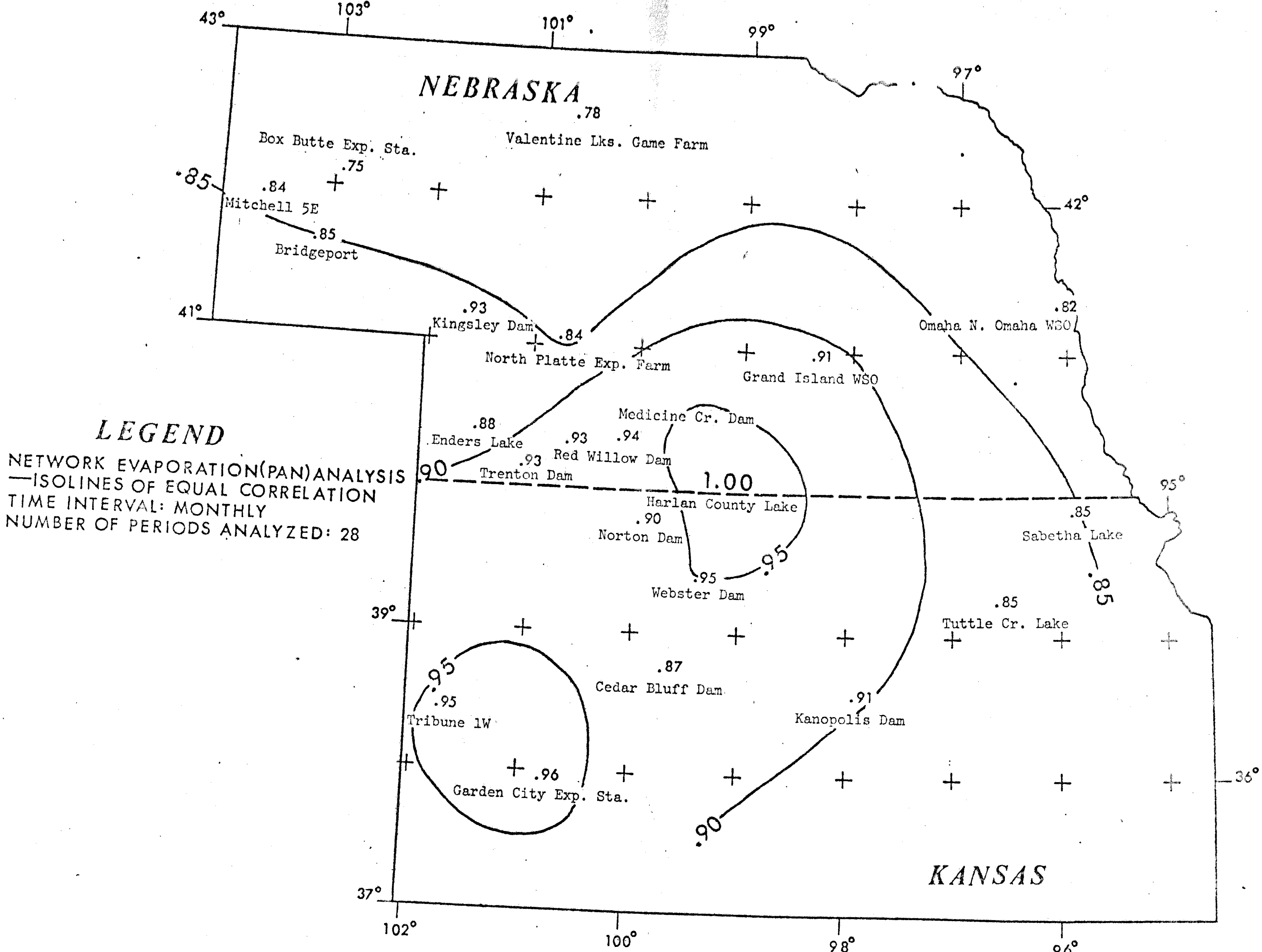
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Tuttle Cr. Lake
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Kanopolis Dam
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Tribune 1W
.96
Garden City Exp. Sta.
.85
.90
.95
.90

Figure 1.

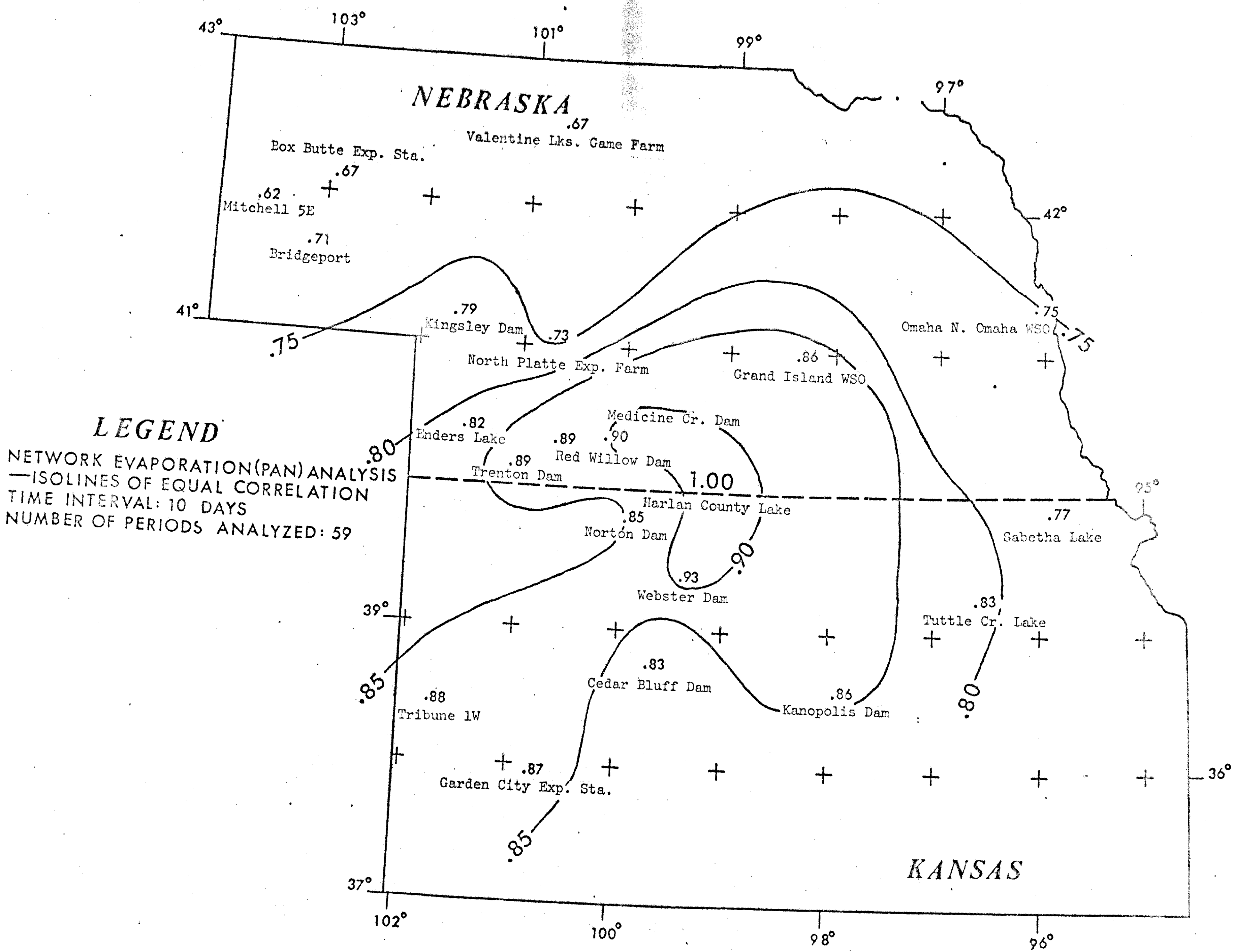

NEBRASKA
KANSAS
43°
41°
39°
37°
36°
42°
103°
101°
99°
97°
95°
102°
100°
98°
96°
.67
Valentine Lks. Game Farm
Box Butte Exp. Sta.
.67
.62
Mitchell 5E
.71
Bridgeport
.79
Kingsley Dam
.73
North Platte Exp. Farm
.86
Grand Island WSO
.75
Omaha N. Omaha WSO
.82
Enders Lake
.89
.90
Medicine Cr. Dam
Red Willow Dam
.89
Trenton Dam
1.00
Harlan County Lake
.85
Norton Dam
.93
Webster Dam
.77
Sabetha Lake
.83
Tuttle Cr. Lake
.83
Cedar Bluff Dam
.86
Kanopolis Dam
.88
Tribune 1W
.87
Garden City Exp. Sta.
.75
.80
.85
.90
LEGEND
NETWORK EVAPORATION(PAN) ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: 10 DAYS
NUMBER OF PERIODS ANALYZED: 59

Figure 2.

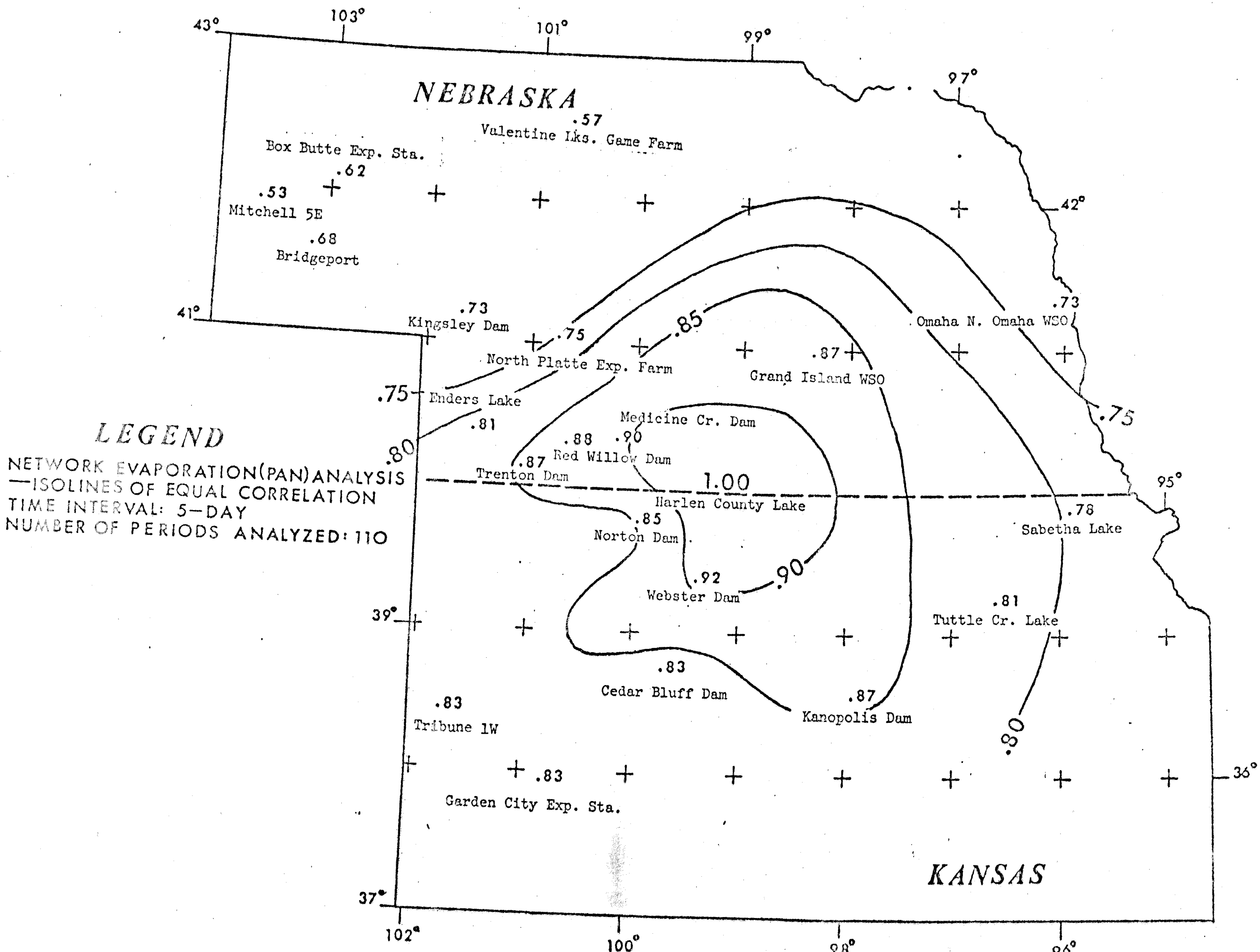
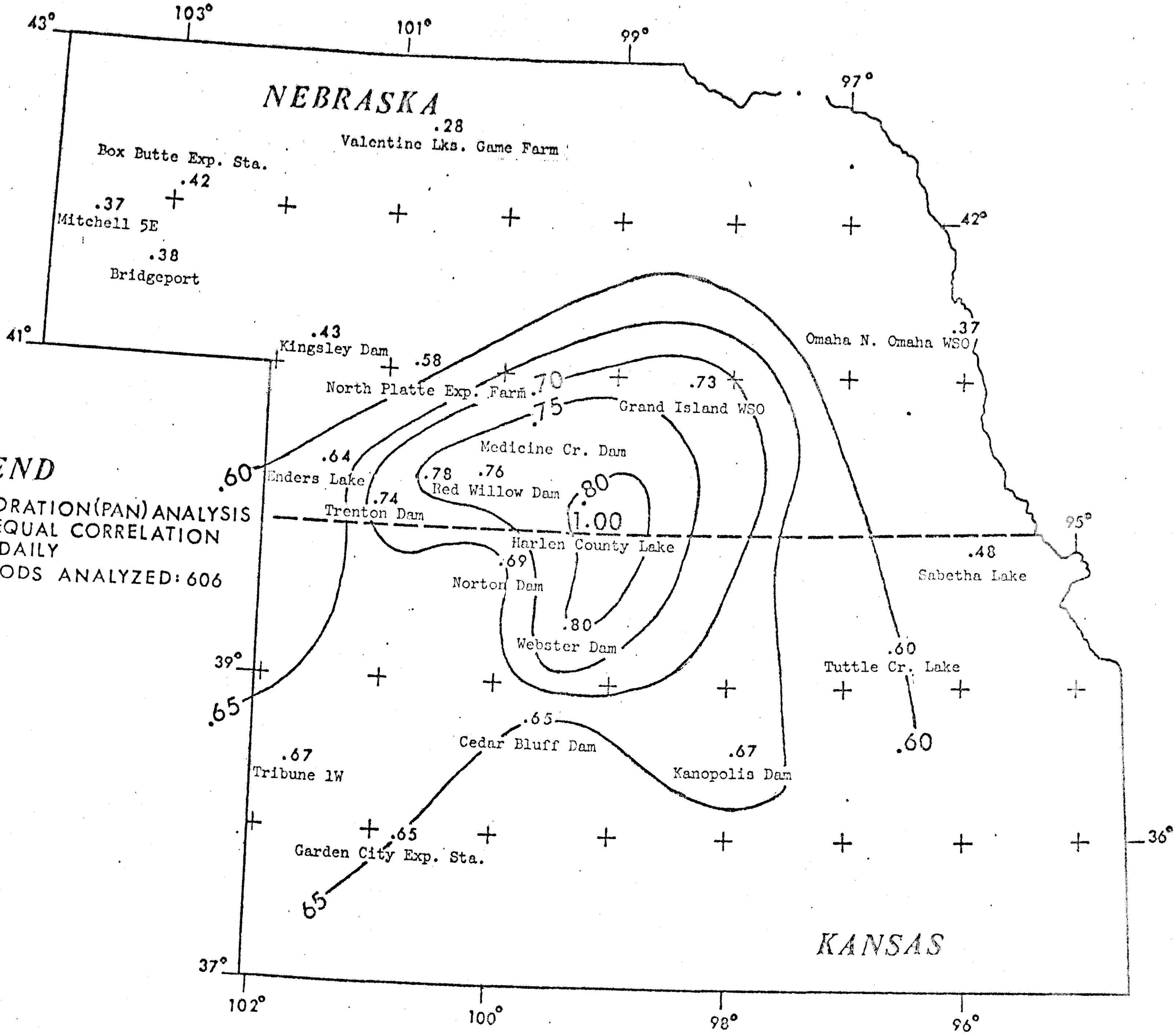

NEBRASKA
KANSAS
43°
103°
101°
99°
97°
42°
41°
39°
37°
102°
100°
98°
96°
95°
36°
.57
Valentine Lks. Game Farm
Box Butte Exp. Sta.
.62
.53
Mitchell 5E
.68
Bridgeport
.73
Kingsley Dam
.75
North Platte Exp. Farm
.75
Enders Lake
.81
.80
.85
.87
Grand Island WSO
Omaha N. Omaha WSO
.73
.75
Medicine Cr. Dam
.88
.90
Red Willow Dam
.87
Trenton Dam
1.00
Harlen County Lake
.85
Norton Dam
.92
Webster Dam
.90
.78
Sabetha Lake
.81
Tuttle Cr. Lake
.83
Cedar Bluff Dam
.87
Kanopolis Dam
.80
.83
Tribune 1W
.83
Garden City Exp. Sta.
LEGEND
NETWORK EVAPORATION(PAN)ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: 5-DAY
NUMBER OF PERIODS ANALYZED: 110

Figure 3.




## LEGEND

NETWORK EVAPORATION (PAN) ANALYSIS
—ISOLINES OF EQUAL CORRELATION
TIME INTERVAL: DAILY
NUMBER OF PERIODS ANALYZED: 606

Figure 4.

Figure 5. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

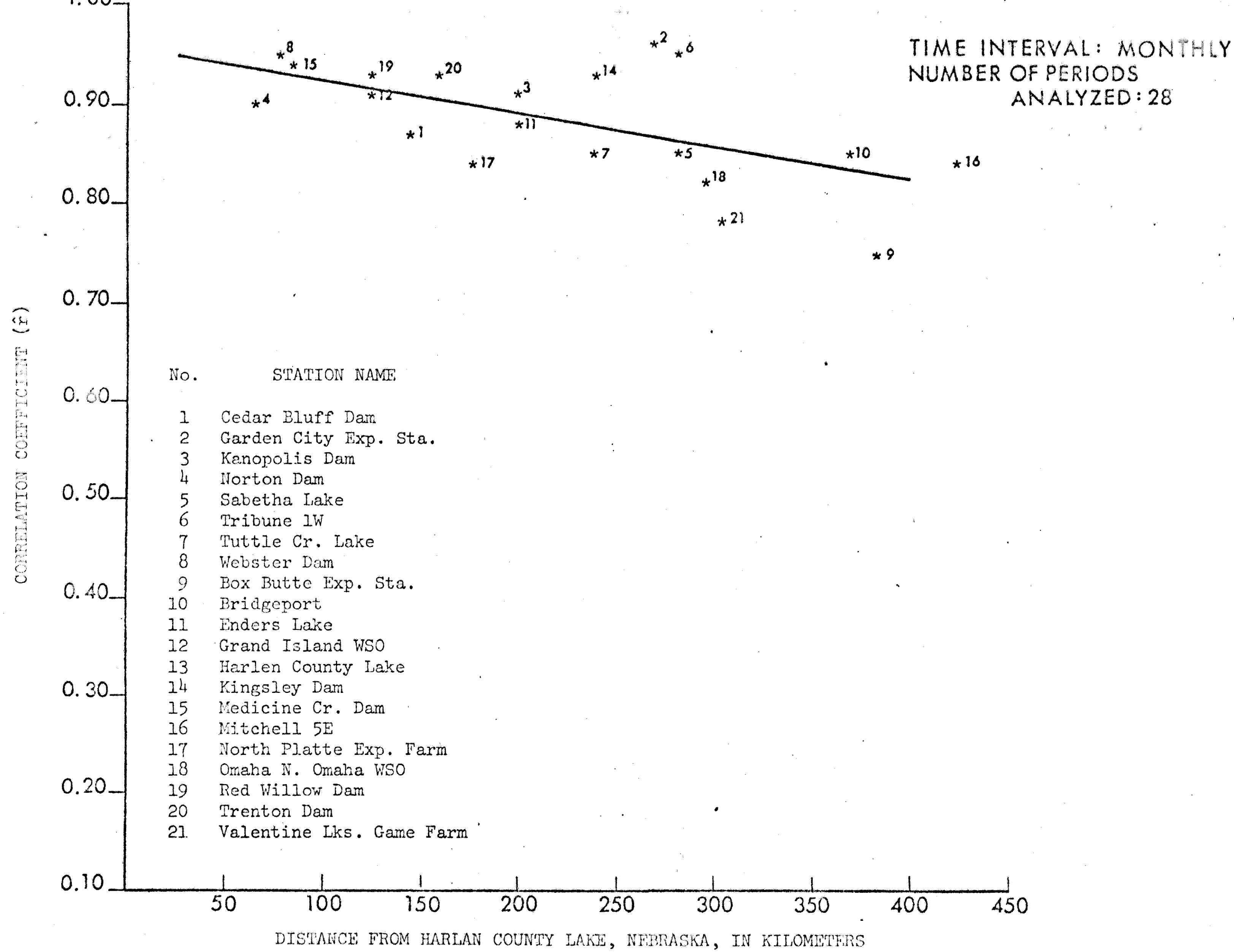


Figure 6. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

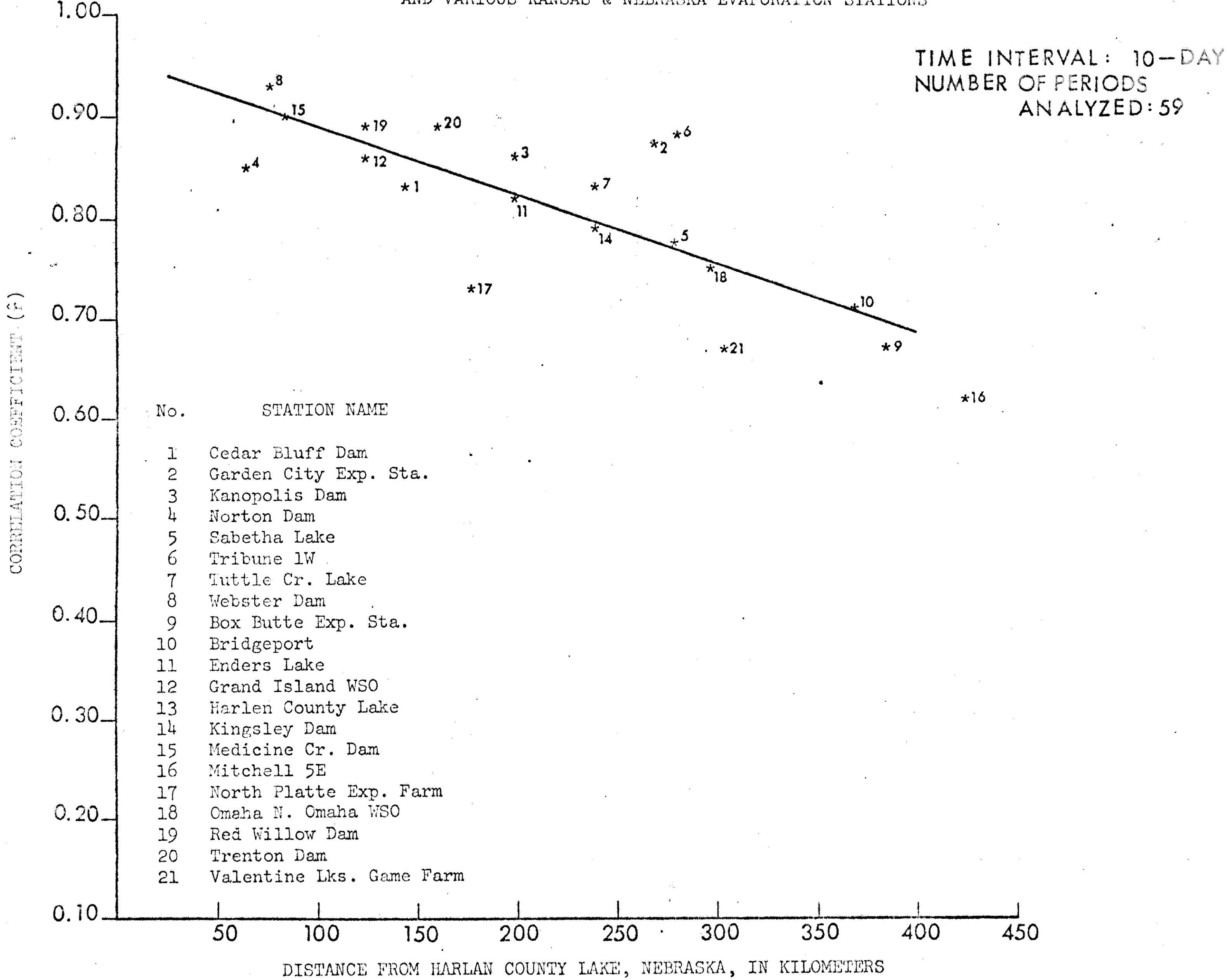


Figure 7. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

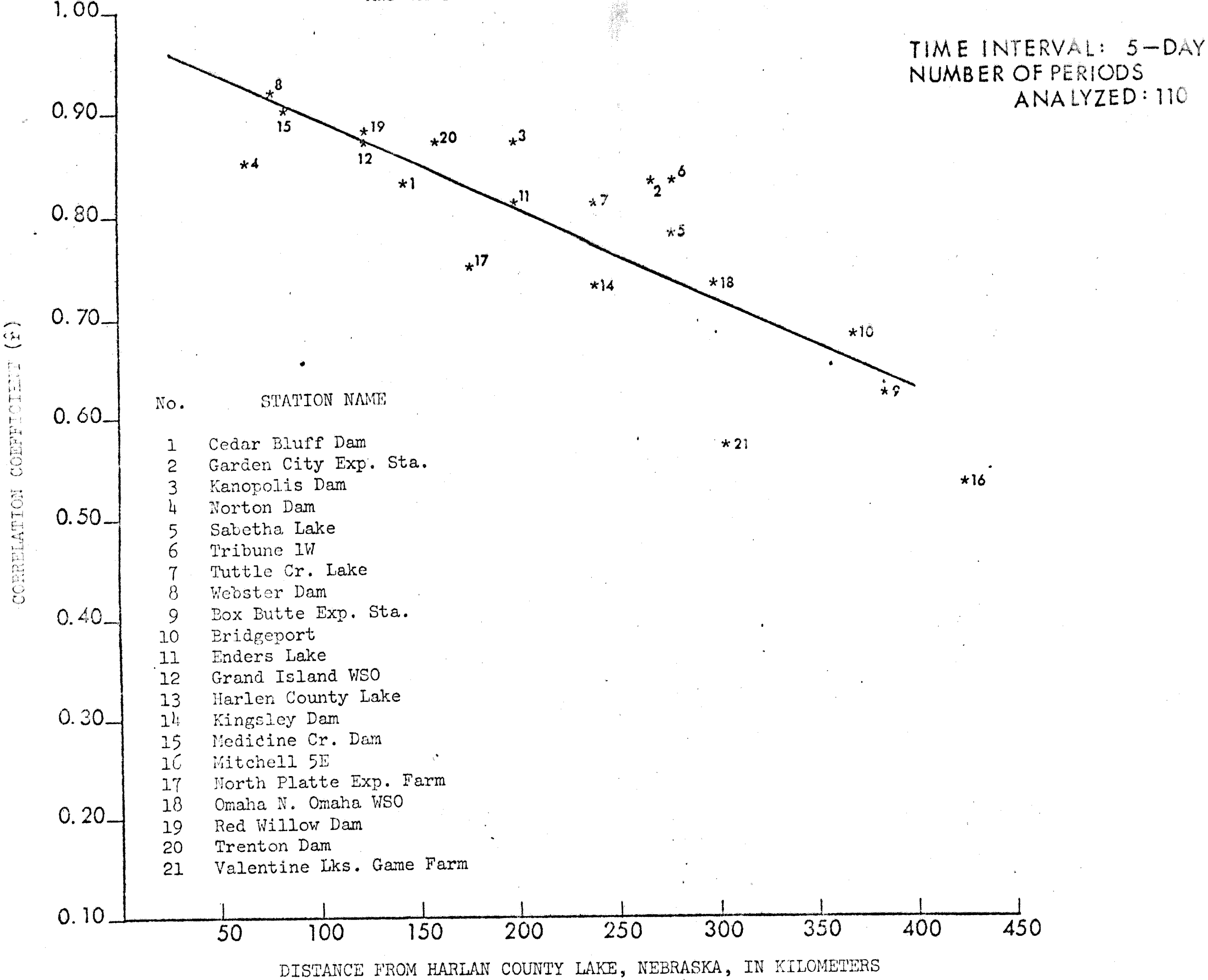


Figure 8.

CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS

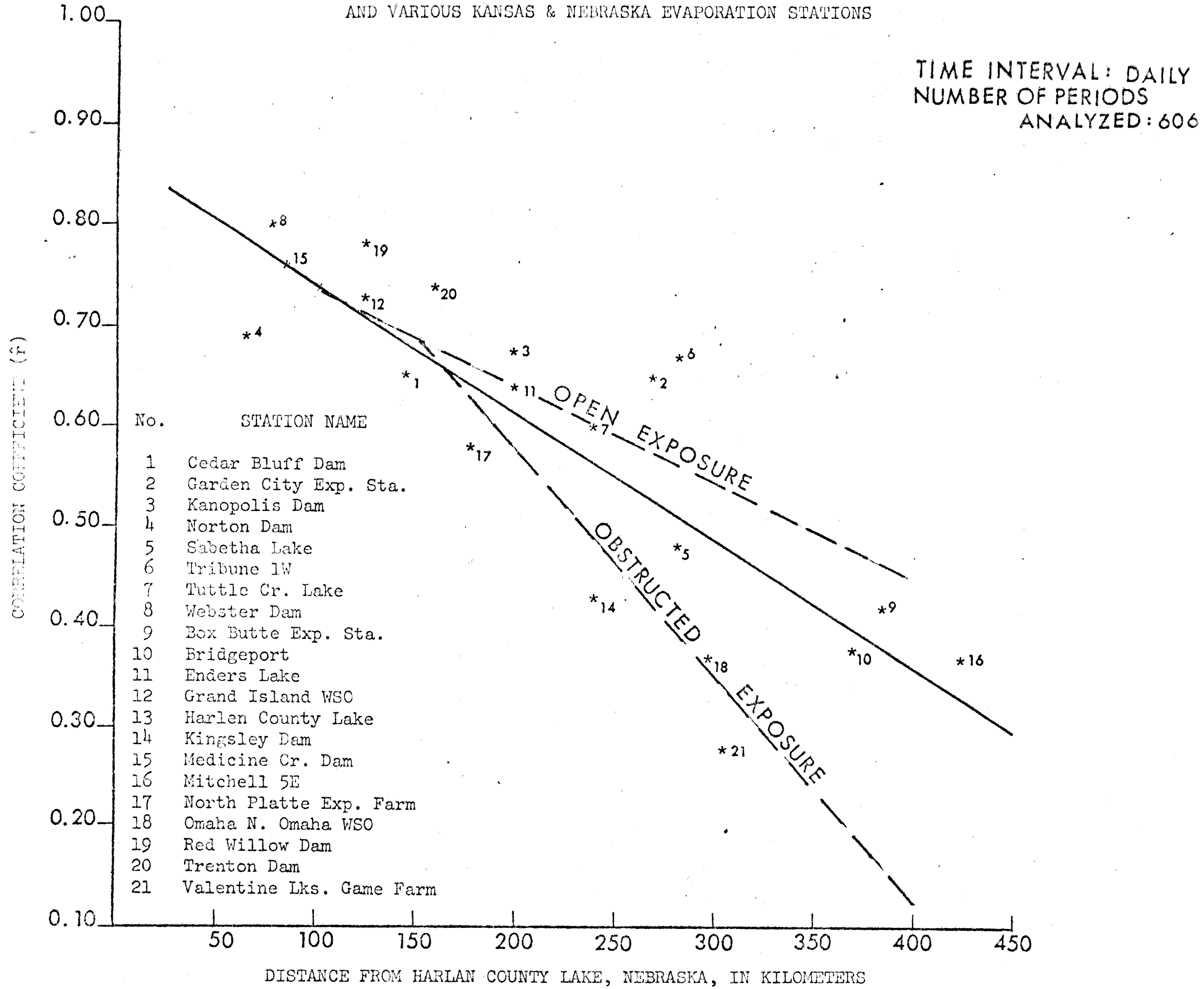
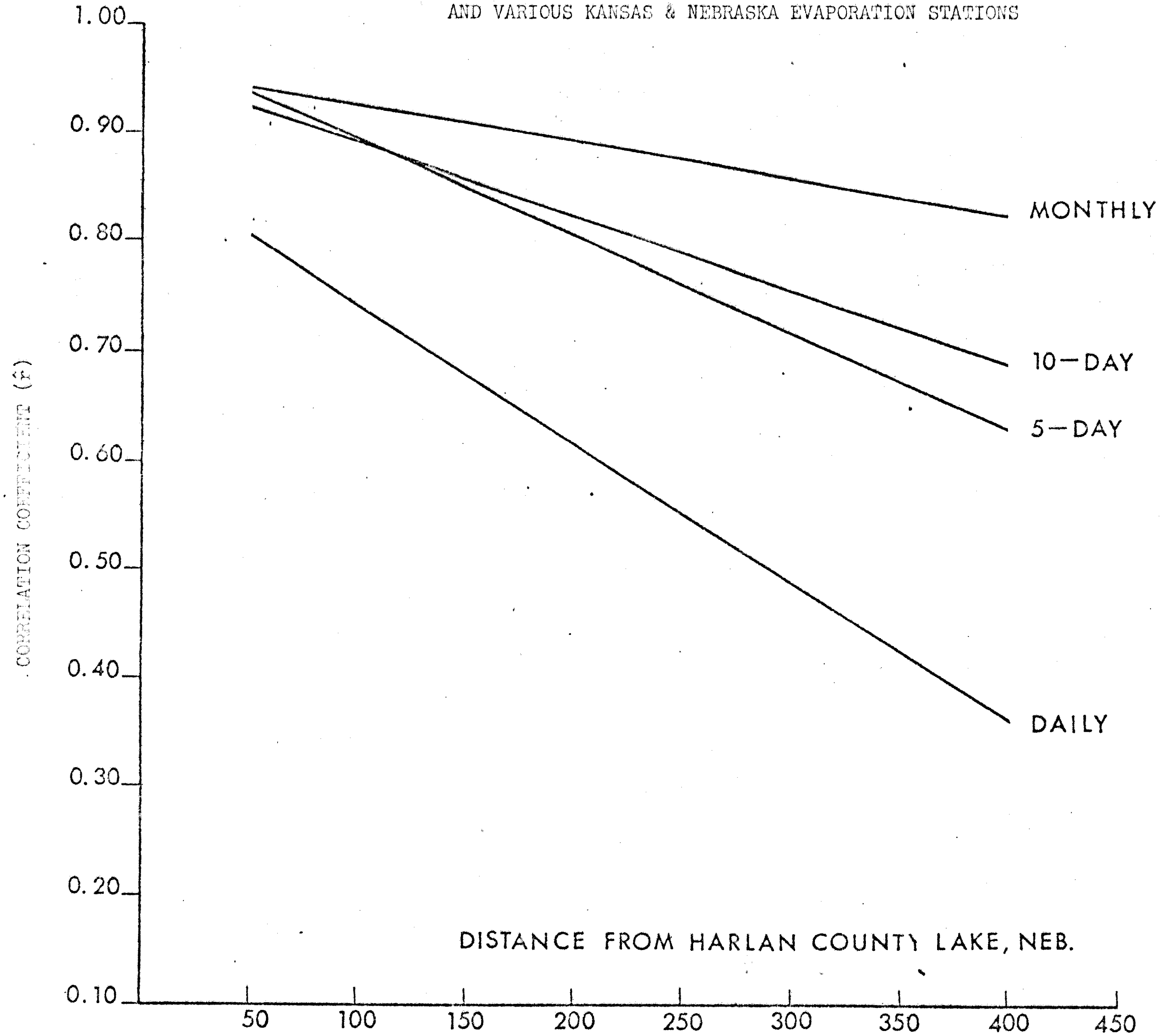
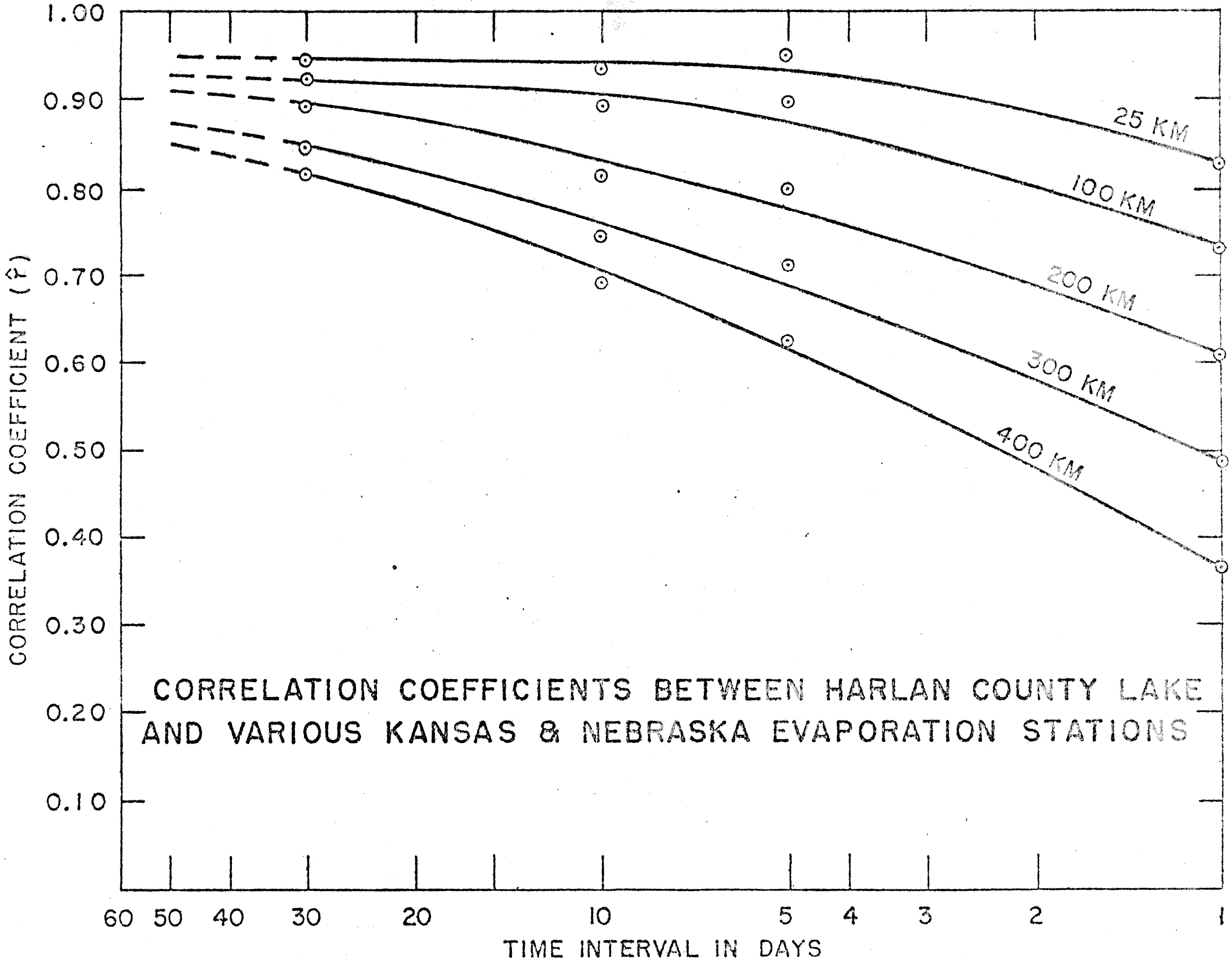


Figure 9. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS





CORRELATION COEFFICIENT ($\hat{r}$)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
25 KM
100 KM
200 KM
300 KM
400 KM
CORRELATION COEFFICIENTS BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS
60 50 40 30 20 10 5 4 3 2 1
TIME INTERVAL IN DAYS


Figure 10.

Figure 11. CORRELATION COEFFICIENT BETWEEN HARLAN COUNTY LAKE AND VARIOUS KANSAS & NEBRASKA EVAPORATION STATIONS