U.S. Weather Bureau.

Cooperative studies report no. 10.

U. S. Department of Commerce
U.S. Weather Bureau

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Bureau of Reclamation

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# MAXIMUM POSSIBLE RAINSTORM

# SWAN LAKE BASIN, REVILLAGIGEDO ISLAND, ALASKA



Prepared by

Cooperative Studies Section
Division of Climatological and Hydrologic Services



Washington, D. C.
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# COOPERATIVE STUDIES REPORTS

No. 1. An Estimate of Maximum Possible Flood-Producing Meteorological Conditions, Big Horn River Basin above Boysen Dam Site. January 1946.

No. 2. Maximum Possible Flood-Producing Meteorological Conditions, East Muddy Creek Basin above Spring Creek Dam Site. August 1946.

No. 3. Maximum Possible Flood-Producing Meteorological Conditions, Taylor River Basin above Almont Dam Site and Taylor Park Dam. February 1947.

No. 4. Maximum Possible Flood-Producing Meteorological Conditions, Plateau Creek Basin above Vega Dam Site. April 1947.

No. 5. Maximum Possible Flood-Producing Meteorological Conditions, Willow Creek Basin above Haystack Dam Site. May 1947.

No. 6. Maximum Possible Flood-Producing Meteorological Conditions, Rifle Creek Basin above Rifle Gap Dam Site. June 1947.

No. 7. Maximum Possible Flood-Producing Meteorological Conditions, Gunnison River Basin above Sapinero Dam Site. July 1947.

No. 8. Maximum Possible Flood-Producing Meteorological Conditions, North Fork of the Gunnison River Basin above Bardine Dam Site. August 1947.

No. 9. Maximum Possible Flood-Producing Meteorological Conditions, (1) Colorado River Basin above Glen Canyon Dam Site, (2) Colorado River Basin above Bridge Canyon Dam Site, (3) San Juan River Basin above Bluff Dam Site, (4) Little Colorado River Basin above Coconino Dam Site. June 1949.

## Chapter I

## INTRODUCTION

Assignment

1. Authorization for this report was contained in a letter dated October 4, 1949 from the Director, Branch of Project Planning, Bureau of Reclamation to the Chief, Climatological and Hydrologic Services, U. S. Weather Bureau. The letter requested study of the maximum possible precipitation above Swan Lake Outlet. Additional details were given in the Speedletter of September 23, 1949 from the Chief, Hydrology Division to the Director, Branch of Project Planning. This letter stated that the study was to be in the nature of a preliminary estimate and that the seasonal variation of the maximum possible precipitation should be determined.

Aspects of Problem

2. There are no precipitation gages in the basin, which lies in a region having few long-period meteorological records. Even where such records are available the rugged topography precludes their being considered as representative for any area beyond the immediate vicinity of the reporting station. This is especially true of the precipitation records. The small size of the basin (approximately 38 sq. mi.) necessitates an approach which considers maximum point rainfall values rather than the usually more reliable large-area values obtained by depth-area-duration analysis so that the absence of storm studies in the region does not present much of a handicap. Fortunately, the basin is located in a region where heavy storm precipitation is nearly always

Chapter I

INTRODUCTION

Authorization

1. Authorization for this report was contained in a letter of October 4, 1945 from the Director, Branch of Project Planning, Bureau of Reclamation to the Chief, Climatological and Hydrologic Services, U. S. Weather Bureau. The letter requested study of the maximum possible precipitation of the Aven Lake Outlet. Additional details were given in the second letter of September 21, 1946 from the Chief, Hydrologic Division to the Director, Branch of Project Planning. This letter stated that the study was to be in the nature of a preliminary estimate and that the seasonal variation of the maximum possible precipitation should be determined.

[illegible] of Records

2. There are no precipitation gages in the basin which lies in a region having the [illegible] of meteorological records. Even where records are available the rugged topography precludes their being considered as representative for any area beyond the immediate vicinity of the reporting station. This is especially true of the precipitation records. The small size of the basin (approximately 25 sq. mi.) necessitates an approach which considers maximum point rainfall values rather than the usually more reliable large-area values obtained by depth-area-duration analysis so that the absence of storm studies in the region does not present much of a handicap. Furthermore, the basin is located in a region where heavy short precipitation is mostly, [illegible]

## CHAPTER II

## MAXIMUM POSSIBLE RAINSTORM

### Storm Data Used in Deriving Maximum Possible Rainstorm

3. The highest 24-hr precipitation occurring each year at each of the stations having mean annual precipitation of 50 inches or more in the coastal regions bordering the Gulf of Alaska and the Northeast Pacific were tabulated from climatological summaries. Records for stations in western Washington and Oregon were included in the survey to supplement the data from Alaskan and British Columbian stations which were relatively few (Alaska 21, B.C. 16). With very few exceptions, the 24-hr amounts thus obtained refer to precipitation occurring in a specified 24-hr period (e.g., between 6 PM observation times) and not, except fortuitously, to the 24-hr period of most intense precipitation in a storm. The few stations having mean annual precipitation of less than 50 inches were not used because inspection of topography in their vicinity indicated that there were high, unbroken mountain barriers to the south, or windward, -- a characteristic not existing in or near the project basin.

4. Using only annual maximum 24-hr amounts for stations having 10 or more years of record, the upper decile values were cmputed by Gumbel's method.[1] These values represent the 24-hr amounts that could be expected to be exceeded once in 10 years. The upper decile values were used instead of the annual maximum 24-hr amounts because, as shown by correlating each to the mean annual precipitation, the former are much more representative of the climate.

[1] LINSLEY, R.K., Jr., M.A. KOHLER and J.L.H. PAULHUS, "Applied Hydrology " pp. 554-555, McGraw-Hill, New York, 1949.

Analysis of Topographic Influences

5. The small range in elevation of stations in Alaska and British Columbia (none higher than 600 ft) was a serious handicap in attempts to determine topographic influences on storm precipitation. Washington and Oregon stations show a much greater range in elevation, and an attempt was made to introduce their data into the correlations. However, elevation did not appear to be a significant parameter, and the data were eliminated from the correlations since they did not improve the results. Washington and Oregon data were used, however, to verify that the topographic parameter finally selected as being the most significant of all those tested with Alaskan and British Columbian data was also highly significant in Washington and Oregon.

6. Many parameters were tested but the only one found to be highly significant was the one called "slope index". Using a template such as shown in Fig. 1 on a topographic map with point 0 on the station, the heights (H) of the highest effective barriers (in thousands of feet) along AB and along BC (East-West line through station) were obtained and the difference between the two ($H_{AB}$-$H_{BC}$) was divided by the distance between the barriers, using a minimum distance of 5 miles and a maximum of 22.5 miles. In the case of negative differences it cannot be inferred that a certain amount of downslope action would cause a decrease in precipitation equal to the increase resulting from the same amount of upslope lifting. Consequently, tests were made using various fractional coefficients for the negative values, but the best correlation was obtained when the negative differences were assigned a value of zero, and they were therefore neglected in computing the slope index.

The barrier-height differences along the other 6 radials, or directions, were determined in the same manner, each divided by the distance between barriers, and the total of the ratios for all 7 radials was called the <u>slope index</u>.

7. The slope index (S) was then correlated with the upper decile values (P) of the annual maximum 24-hr precipitation (Fig.2), yielding a correlation coefficient of .86, which is highly significant at the 1-percent level for 37 items. The regression equation is $P = 3.62 + 2.73S$. Correlation of the actual upper decile precipitation values with those computed by the regression equation showed a standard error of 0.75 in., which is 17% of 4.44 in., the average of the upper decile values. Although the upper portion of the regression line appears to be controlled by only two stations, a regression line based on the remaining 35 items gave a computed upper decile value of 24-hr precipitation that was only 0.4 in. less for the average slope index (0.73) of the basin. A regression based on Washington and Oregon data was quite similar also.

<u>24-Hour Basin Storm Expected to be Exceeded Once in Ten Years</u>

8. Using a topographic map of the basin and surrounding area and the template of Fig. 1, the slope index (par.6) was computed for 41 points determined by the intersections of a 1-mi grid superimposed on the basin. The upper decile value of the maximum 24-hr precipitation at each point (Fig.3) was then computed from Fig. 2, and the average for the 41 points (5.6 in.) is the 24-hr storm that might be expected to be exceeded once in 10 years.

9. Since the computed upper decile 24-hr amounts showed a

standard error of ±0.75 in. from the actual (par.7), roughly two-thirds of the computations would, under the usual assumption of normal distribution, yield results departing from the actual upper decile values by not more than 0.75 in. Similarly, over 99% of the computations would be expected to yield values within 2.25 in. (thrice the standard error) of the actual. Consequently, under the same assumptions there is very little chance that the computed basin average of 5.6 in. (par.8) is too low by much more than 2.2 in. Even under the assumption of the worst distribution possible, the probability that the value of 7.8 in. would be exceeded is 0.11, according to Tchebycheff's Inequality[1].

Estimated Maximum Actual 24-Hour Precipitation

10. In order to estimate the maximum 24-hr precipitation that has probably occurred over the basin during the period covered by Alaskan climatological records (10 to 30 years), the ratios of the maximum 24-hr precipitation to the upper decile value for each of the ten stations nearest the basin were determined and their geometric mean computed (Table 1). This mean ratio (1.13) was used to adjust the 1-in-10-yr 24-hr basin average (par.8) to 6.3 in., the maximum 24-hr amount that has probably occurred over the basin within the 10 to 30 years.

Seasonal Variation of Maximum Possible Precipitation

11. The maximum 24-hr precipitation for each of the 10 stations near the basin was determined for each month of every year by inspection of the climatological records. The upper decile value of the maximum

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[1]HOEL, P.G., "Introduction to Mathematical Statistics," pp. 172-173, Wiley & Sons, New York, 1947.

24-hr precipitation for each month was then computed by Gumbel's method. The upper decile values for each month for each station were then converted to percent of the station October value, which was the highest for the year at 8 stations. Plotting only the highest percentage value of the 10 stations for any particular month and smoothing by the formula (A + 2B + C)/4, the seasonal variation curve of Fig. 4 was obtained. Mid-October is evidently the optimum time for the occurrence of maximum 24-hr precipitation amounts and the maximum possible storm precipitation can be reasonably expected then.

Maximum Possible 24-Hour Precipitation

12. The moisture charge adjustment factor was derived by using the representative 12-hr dewpoints associated with the maximum observed 24-hr precipitation at each of the 10 stations near the basin (Table 1). The precipitable water (Wpo) in the layer between the tops of the effective inflow barriers and the 200-mb level was computed, under the usual assumption of a pseudoadiabatic saturated atmosphere. The precipitable water (Wpm) was also computed for the maximum persisting 12-hr dewpoints ever observed at the same time of year the maximum 24-hr precipitation occurred. The geometric mean of the ratios (Wpm/Wpo) for all 10 stations was then determined to be 1.49 and is the factor for adjusting the estimated maximum 24-hr precipitation over the basin (par. 10) for maximum moisture charge.

13. A seasonal factor is required to adjust the estimated maximum 24-hr amount over the basin to mid-October since most of the maximum observed 24-hr precipitation amounts occurred at other times.

Accordingly, the ratio of the top value (100) from the seasonal variation curve (Fig. 4) to the value (on the same curve) for the date the maximum 24-hr precipitation was observed (Table 1) was computed for each of the 10 stations. The seasonal factor is the geometric mean of these 10 ratios, or 1.05 (Table 1).

14. The estimated maximum 24-hr precipitation over the basin (6.3 in.) is then raised to the maximum possible by applying the combined moisture charge and seasonal variation factors (1.57). The computation gives an average depth over the basin of 9.9 in. for the best estimate of the maximum possible 24-hr precipitation. However, allowing a departure of three times the standard error (3 x 0.75) from the regression of Fig. 2, the upper limit of the maximum possible 24-hr precipitation could be (1.13 x 1.57) x (6.3 + 2.2), or 15.0 in.

Depth-Duration Relationship of Maximum Possible Rainstorm

15. The determination of the maximum possible precipitation has thus far been limited to the 24-hr duration. In order to derive a depth-duration relation, the maximum precipitation amounts of record for various durations were obtained from climatological records for Juneau and Ketchikan, the only two stations near the project basin for which these data were available. The maximum amounts for each duration were converted to percent of the maximum 24-hr amount for the particular station, plotted, and then enveloped by the curve of Fig. 5. Although this method does not require that the maximum amounts for the various durations occur in the same storm, the values controlling the curve for durations of 24 hours and longer did occur in one storm, August 4-6, 1920.

On that occasion Ketchikan, which is only 21 miles from the basin, recorded 7.10 in. on the 4th, 8.07 in. on the 5th, and 4.37 in. on the 6th. Application of the depth-duration curve of Fig. 5 to the various 24-hr amounts already computed yields the depth-duration curves of Fig. 6. One of these curves is for the maximum possible rainstorm.

Recurrence of Interval of Maximum Possible Rainstorm

16. Inspection of the climatological records for stations in the region of the project basin revealed that the daily occurrence of measurable precipitation for 3 consecutive weeks is not unusual during the wet season, namely, fall and winter. The storm of August 4-6, 1920 at Ketchikan shows that near maximum-possible 24-hr amounts can occur on successive days. Study of other stormy periods indicated that heavy 1-day "bursts" could follow this 48-hr period with only a 2-day interval, during which precipitation would continue but with somewhat smaller daily amounts. For example, during the period November 13-20, 1917, Ketchikan reported the following amounts: 13th, 3.47; 14th, 3.90; 15th, 1.97; 16th, 0.28; 17th, 6.61; 18th, 7.13; 19th, 3.40; 20th, 0.66. Accordingly, the recurrence interval between the maximum 1-day amounts of the maximum possible rainstorm was set at 3 days. In other words, a minimum interval of 3 days is permissible between the end of the wettest day of the first storm and the beginning of the wettest day of the second.

Snow Cover at Time of Maximum Possible Rainstorm

17. Although the snow accumulation on the basin would be near

the minimum in October, when the maximum possible rainstorm is most likely to occur, it would be possible for the basin to be fully covered with freshly fallen snow. A full cover of fresh snow is possible at any time from October through May. No attempt was made to estimate the snow accumulation since that item would require considerable study not usually considered as coming within the scope of a preliminary estimate.

Table 1

ADJUSTMENT FACTORS

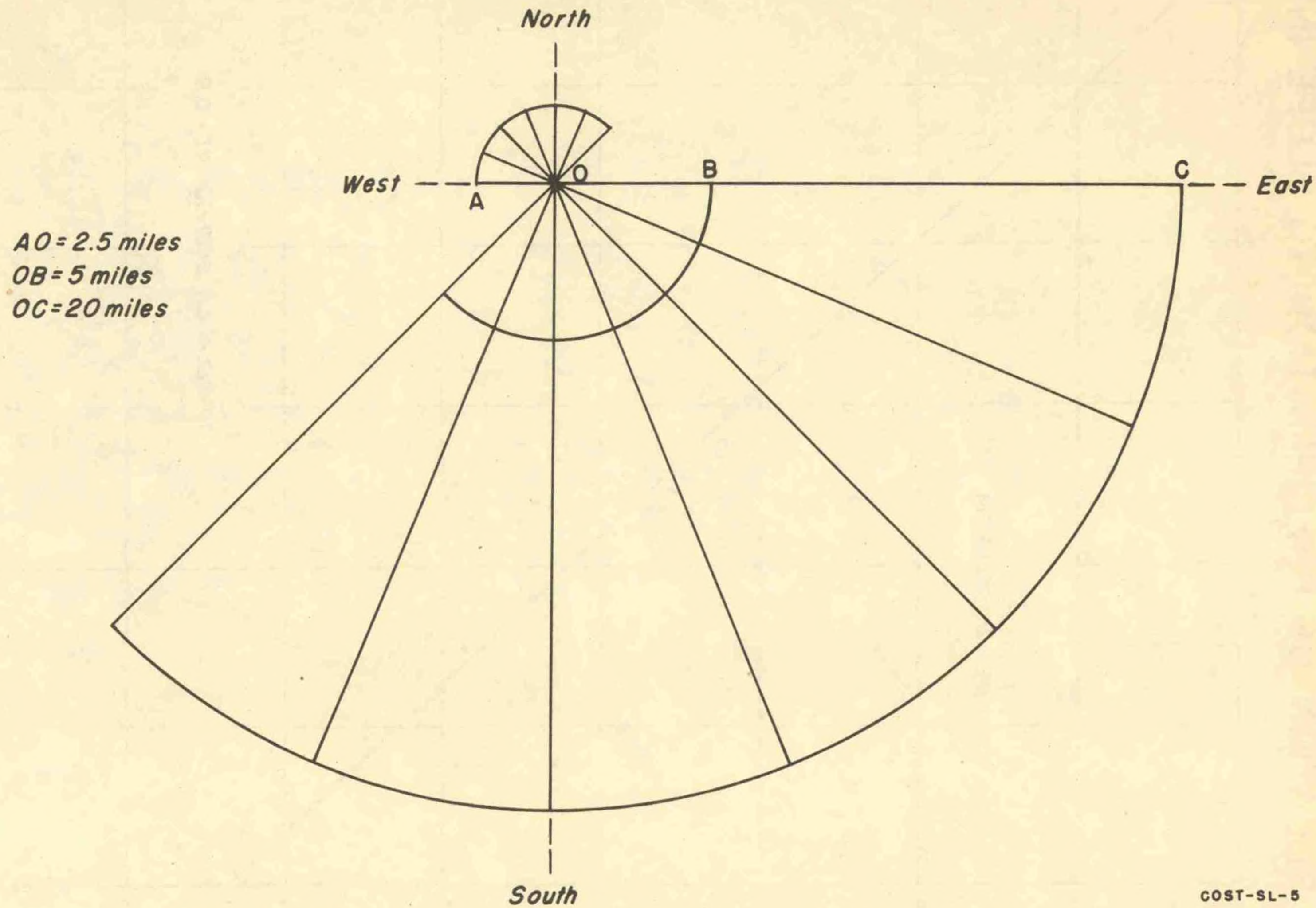
| Station | 24-Hour Precip. (in.) | | | Representative 12-Hour Dewpoint | | | | Adjustment Factors | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Upper Decile | Maximum | | Station | Inflow Barrier | Obs. (°F) | Max. (°F) | Max 24-hr P / Upper Decile | Mois-ture | Sea-sonal |
| | | Amt | Date | | | | | | | |
| Bell Island | 4.20 | 4.60 | 10/2/30 | Tatoosh Is. | 2000 | 52 | 60 | 1.10 | 1.55 | 1.01 |
| Calder | 4.22 | 4.54 | 1/13/22 | Tatoosh Is. | 1500 | 40 | 51 | 1.08 | 1.81 | 1.10 |
| Craig | 4.51 | 5.15 | 10/6/46 | Juneau | 1500 | 44 | 54 | 1.14 | 1.71 | 1.01 |
| Fortman Hatchery | 4.41 | 4.74 | 9/23/22 | Tatoosh Is. | 1500 | 53 | 59 | 1.07 | 1.37 | 1.02 |
| Ketchikan | 6.83 | 8.07 | 8/5/20 | Tatoosh Is. | 0 | 53 | 59 | 1.18 | 1.34 | 1.22 |
| Little Port Walter | 9.87 | 10.94 | 10/9/44 | North Head | 1000 | 52 | 60 | 1.11 | 1.52 | 1.00 |
| Petersburg | 5.25 | 5.70 | 10/21/37 | Tatoosh Is. | 2000 | 55 | 61 | 1.09 | 1.39 | 1.00 |
| Prince Rupert | 3.73 | 4.92 | 1/26/34 | Tatoosh Is. | 1000 | 47 | 51 | 1.32 | 1.23 | 1.11 |
| Tree Point | 3.33 | 3.75 | 10/26/33 | North Head | 0 | 52 | 60 | 1.13 | 1.50 | 1.01 |
| View Cove | 5.14 | 5.51 | 12/15/36 | Tatoosh Is. | 1000 | 44 | 52 | 1.07 | 1.53 | 1.06 |
| | | | | Geometric Means | | | | 1.13 | 1.49 | 1.05 |

Table 2

MONTHLY UPPER DECILE VALUE OF MAXIMUM 24-HOUR PRECIPITATION

| | Jan. | | Feb. | | Mar. | | Apr. | | May | | Jun. | | Jul. | | Aug. | | Sep. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % | (in.) | % |
| Bell Island | 3.00 | 78 | 2.75 | 71 | 2.31 | 60 | 1.86 | 48 | 1.59 | 41 | 1.90 | 49 | 1.74 | 45 | 2.38 | 62 | 2.96 | 77 | 3.85 | 100 | 3.08 | 80 | 2.35 | 61 |
| Calder | 3.30 | 94 | 2.80 | 80 | 2.00 | 57 | 1.89 | 54 | 1.81 | 51 | 1.43 | 41 | 1.25 | 36 | 2.37 | 67 | 3.23 | 92 | 3.52 | 100 | 3.59 | 102 | 3.12 | 89 |
| Craig | 2.89 | 64 | 2.62 | 58 | 2.32 | 51 | 2.35 | 52 | 1.69 | 37 | 1.35 | 29 | 1.49 | 33 | 2.37 | 52 | 2.73 | 60 | 4.53 | 100 | 2.56 | 57 | 2.55 | 56 |
| Fortman Hatchery | 2.73 | 74 | 3.23 | 87 | 2.82 | 76 | 2.65 | 71 | 2.61 | 70 | 2.41 | 65 | 1.72 | 46 | 2.72 | 73 | 3.62 | 98 | 3.71 | 100 | 3.58 | 97 | 3.24 | 87 |
| Ketchikan | 4.16 | 73 | 3.44 | 61 | 4.39 | 77 | 3.24 | 57 | 3.26 | 58 | 2.82 | 50 | 3.21 | 57 | 4.64 | 82 | 4.78 | 84 | 5.67 | 100 | 4.90 | 86 | 3.50 | 62 |
| Little Port Walter | 6.71 | 73 | 4.83 | 53 | 6.45 | 70 | 2.96 | 32 | 4.38 | 48 | 2.87 | 31 | 4.36 | 48 | 5.95 | 65 | 7.45 | 81 | 9.17 | 100 | 8.26 | 90 | 6.03 | 66 |
| Petersburg | 2.86 | 60 | 3.01 | 63 | 2.62 | 55 | 2.06 | 43 | 2.14 | 45 | 1.82 | 38 | 1.59 | 33 | 2.61 | 55 | 3.29 | 69 | 4.76 | 100 | 3.06 | 64 | 2.71 | 57 |
| Prince Rupert | 2.64 | 90 | 2.36 | 81 | 2.17 | 74 | 1.80 | 62 | 1.78 | 61 | 1.42 | 49 | 1.46 | 50 | 2.13 | 73 | 2.35 | 80 | 2.95 | 100 | 2.77 | 95 | 2.23 | 76 |
| Tree Point | 2.19 | 74 | 2.19 | 74 | 1.96 | 66 | 1.91 | 65 | 1.73 | 59 | 2.09 | 71 | 2.08 | 71 | 2.49 | 84 | 2.74 | 93 | 2.95 | 100 | 2.84 | 96 | 2.40 | 81 |
| Wrangell | 2.58 | 90 | 2.41 | 84 | 1.94 | 68 | 1.80 | 63 | 1.16 | 41 | 1.43 | 50 | 1.42 | 50 | 2.57 | 90 | 2.31 | 81 | 2.86 | 100 | 2.93 | 102 | 2.18 | 76 |

# SCALE FOR MEASURING SLOPE INDEX




COST-SL-5

FIGURE 1

# RELATION OF PRECIPITATION TO SLOPE INDEX

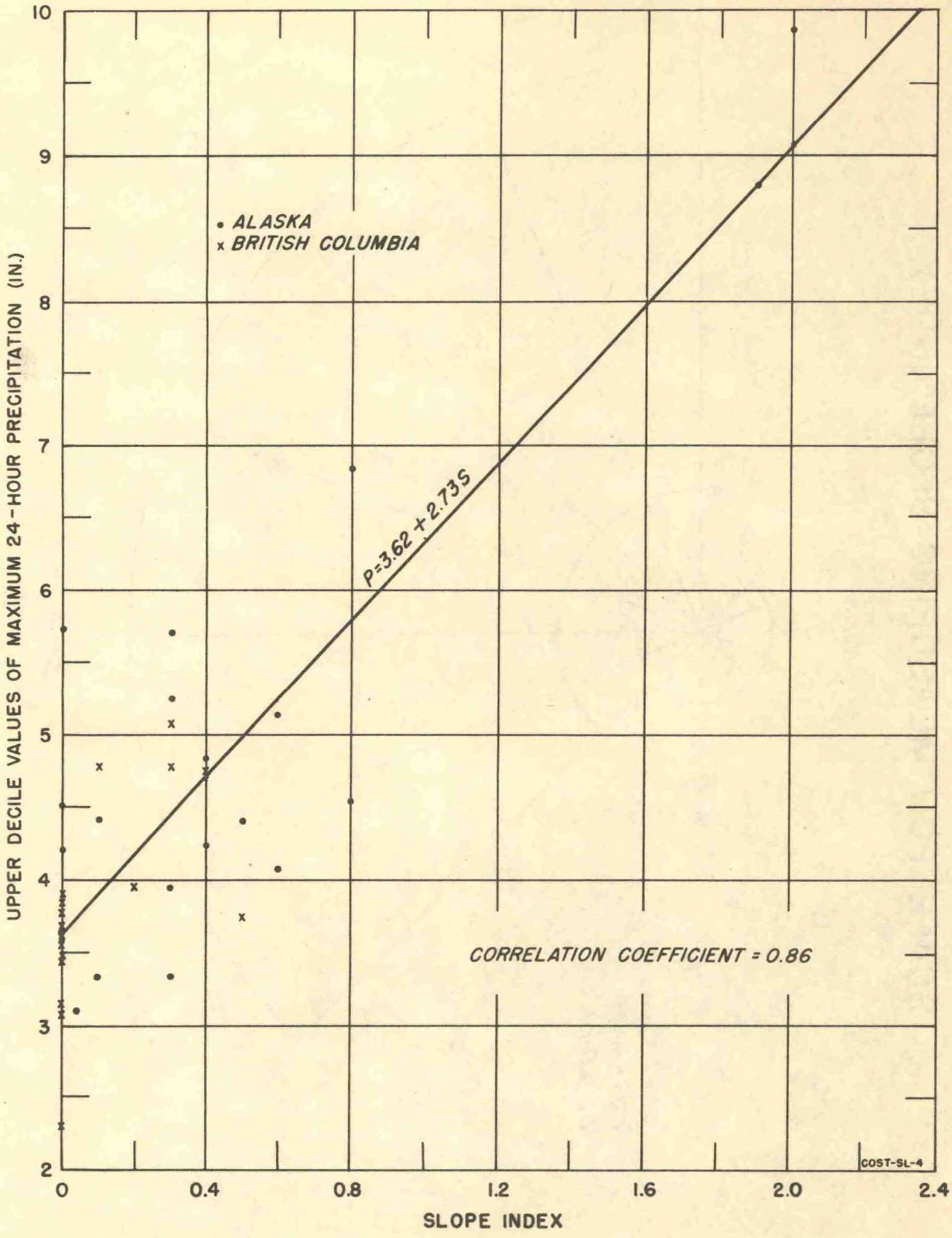
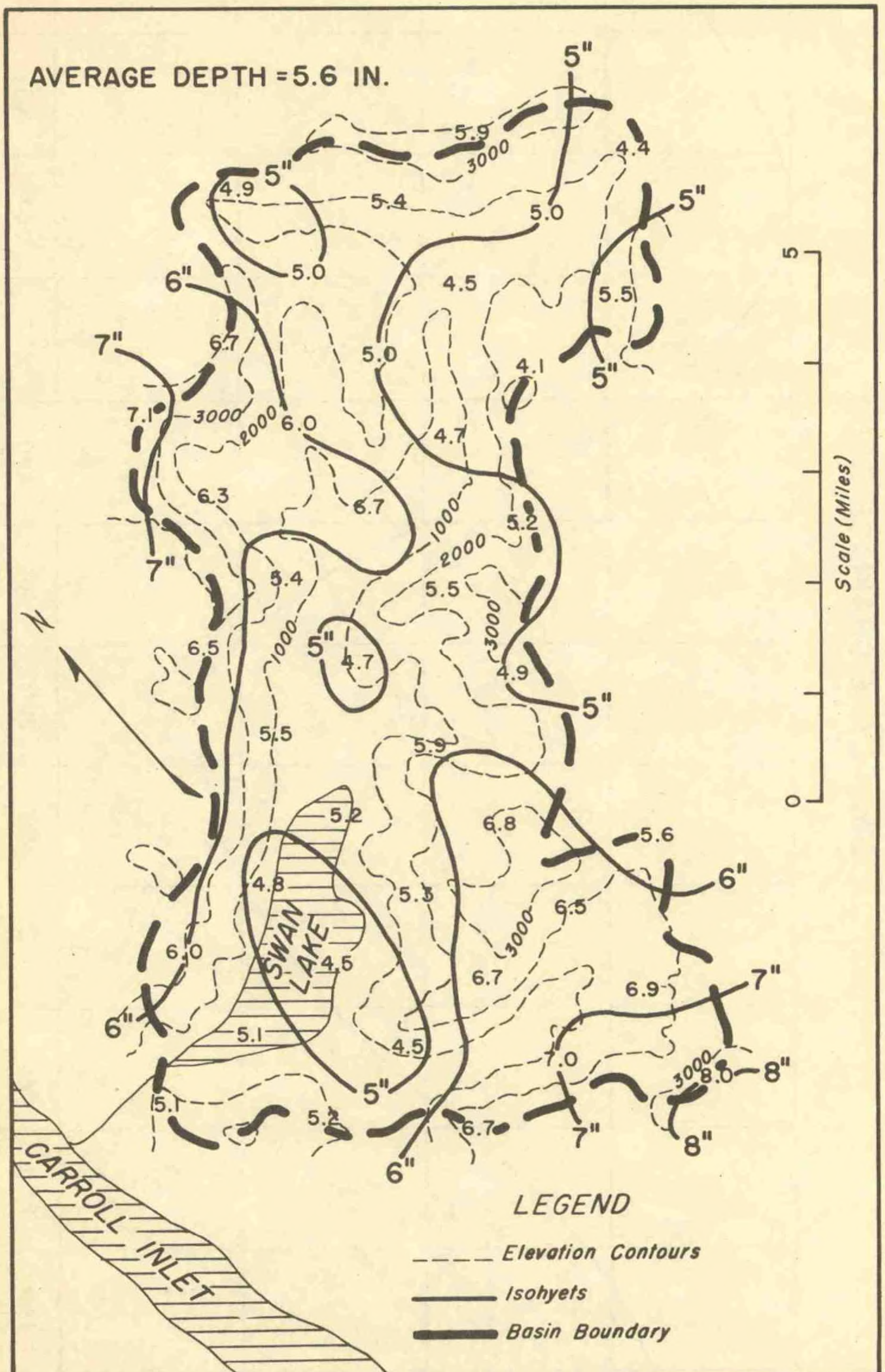



FIGURE 2

# 24-HOUR STORM EXPECTED TO BE EXCEEDED ONCE EVERY 10 YEARS




COST-SL-6

FIGURE 3

# SEASONAL VARIATION OF MAXIMUM POSSIBLE RAINSTORM

## SWAN LAKE DRAINAGE AREA

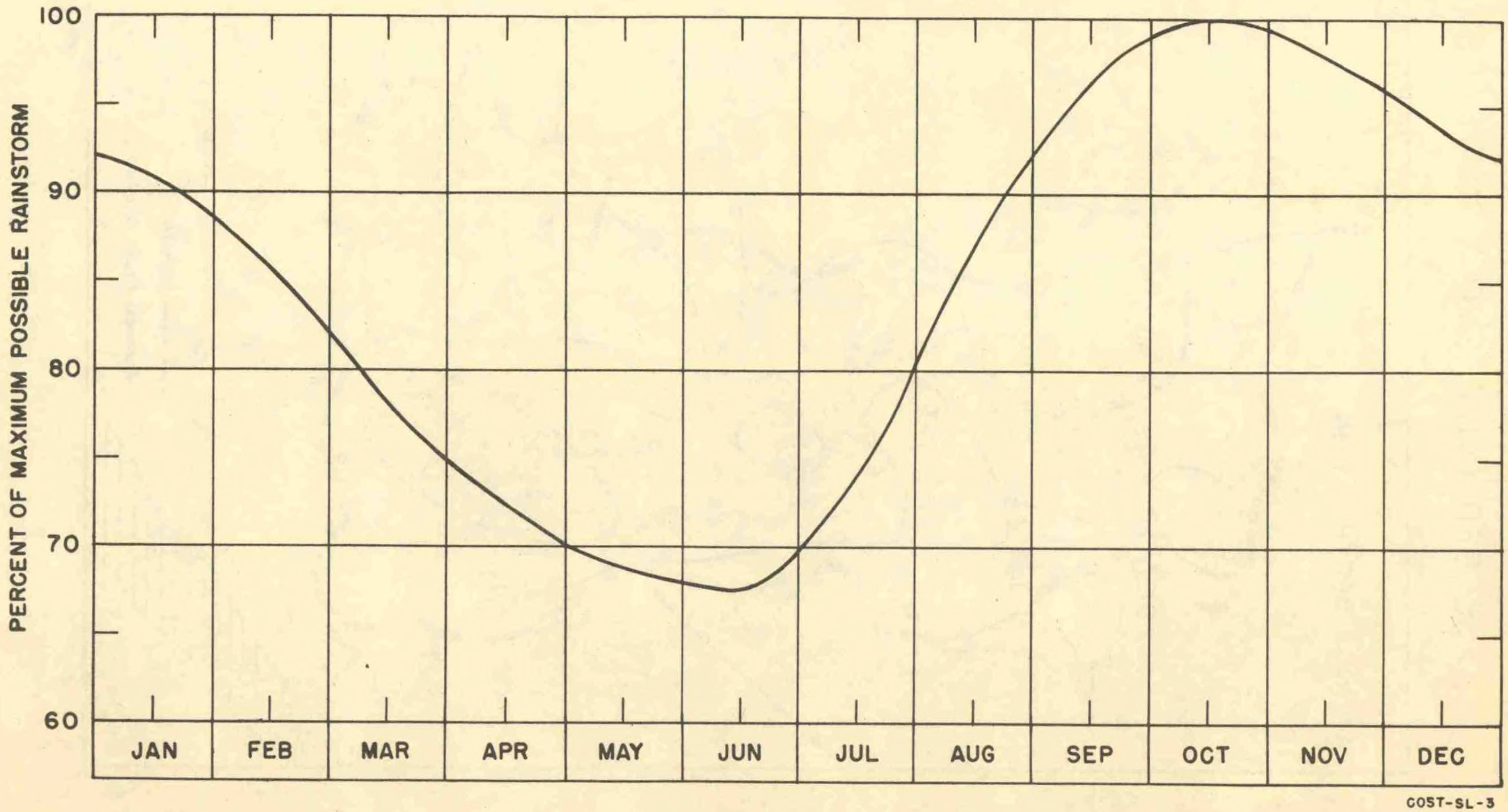



FIGURE 4

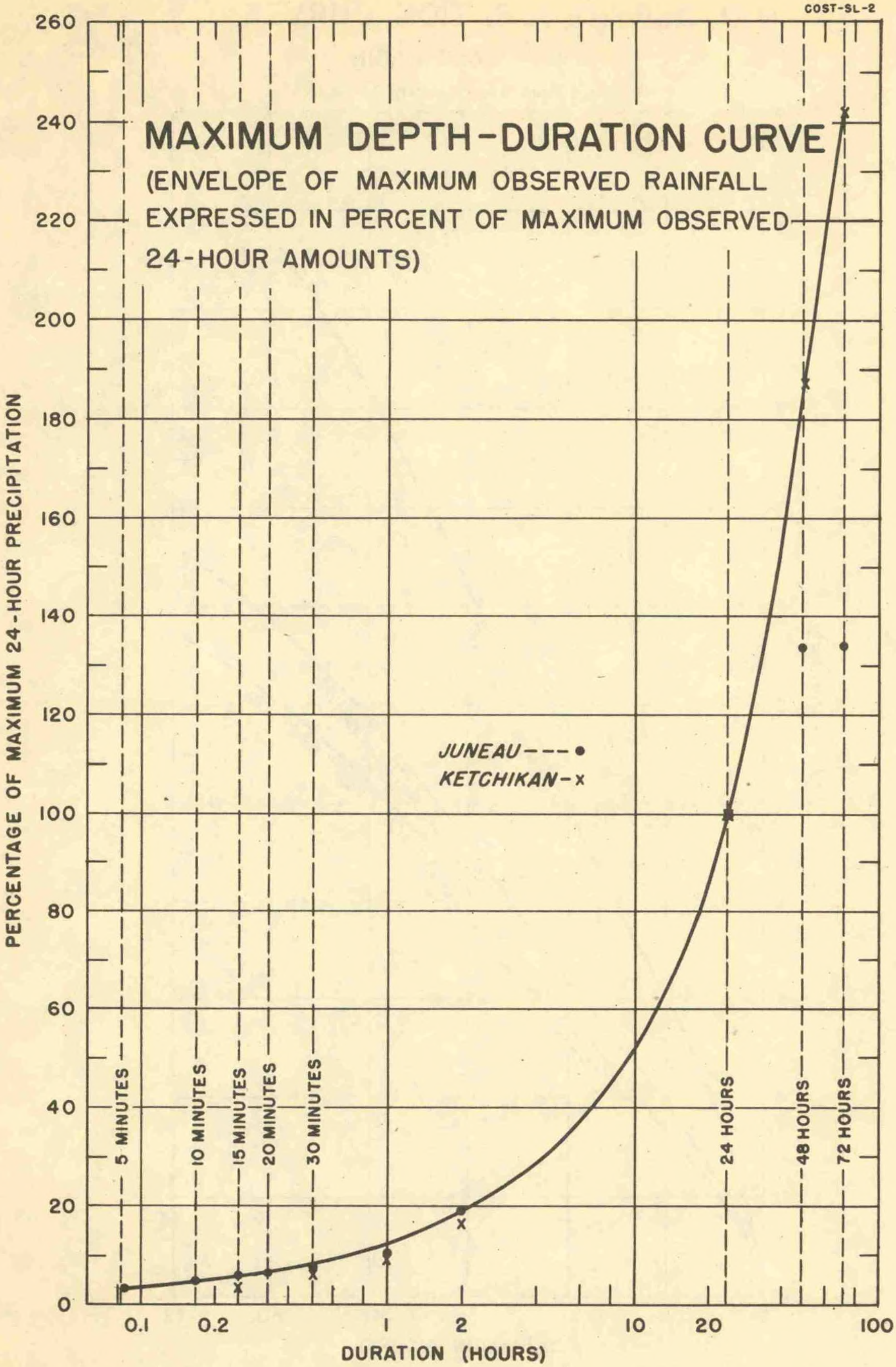

MAXIMUM DEPTH-DURATION CURVE
(ENVELOPE OF MAXIMUM OBSERVED RAINFALL EXPRESSED IN PERCENT OF MAXIMUM OBSERVED 24-HOUR AMOUNTS)
JUNEAU---●
KETCHIKAN-x
5 MINUTES
10 MINUTES
15 MINUTES
20 MINUTES
30 MINUTES
24 HOURS
48 HOURS
72 HOURS
PERCENTAGE OF MAXIMUM 24-HOUR PRECIPITATION
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0.1
0.2
1
2
10
20
100
DURATION (HOURS)

FIGURE 5

# DEPTH - DURATION CURVES

## SWAN LAKE BASIN

(Drainage Area Approximately 38 Sq. Mi.)

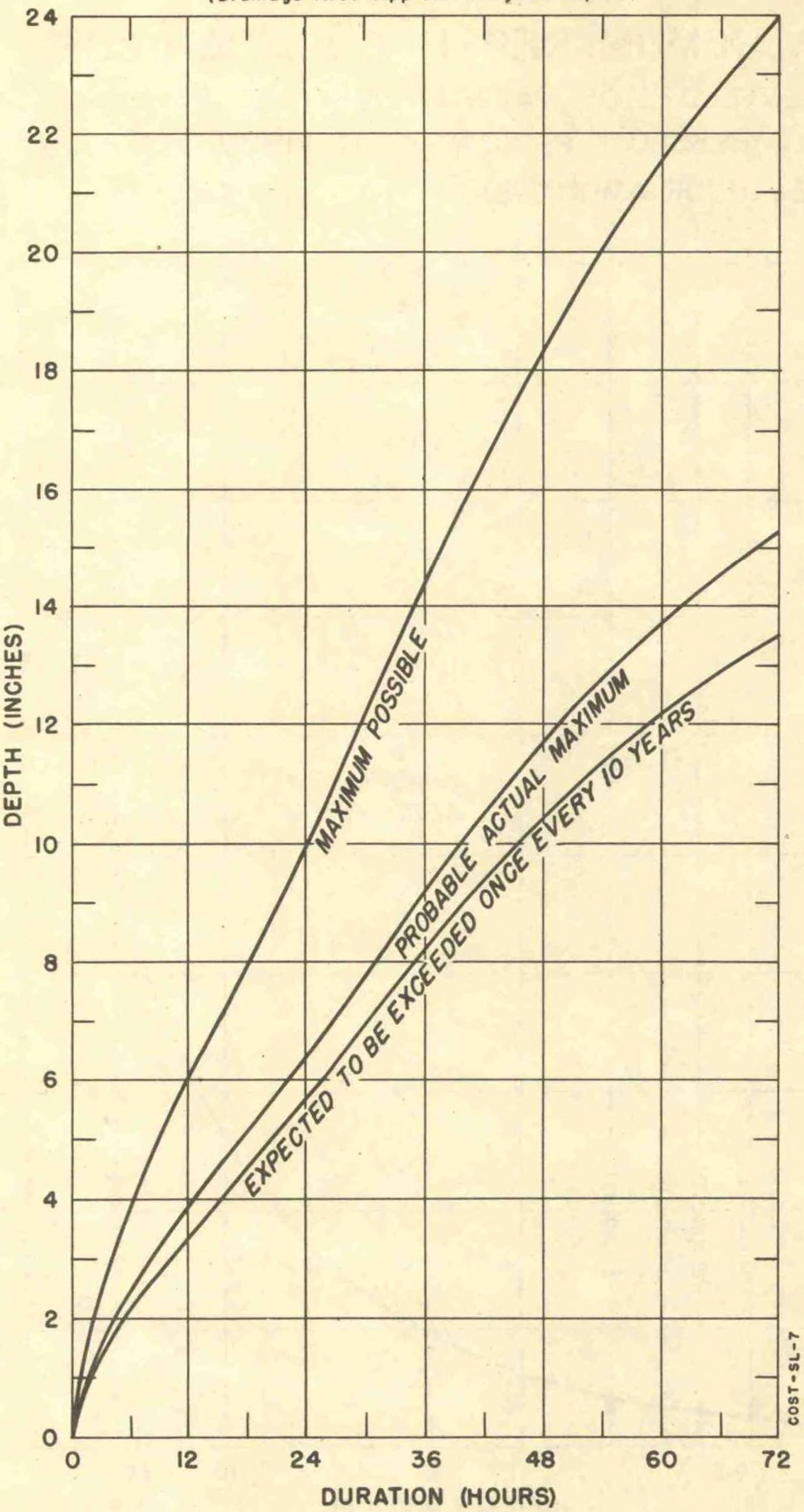



FIGURE 6