# THE ALLUVIAL FAN METHOD FOR ANALYZING FLOOD POTENTIAL AT THE PROPOSED LOW-LEVEL RADIOACTIVE WASTE ISOLATION SITE, HUDSPETH COUNTY, TEXAS

by

M. Saleem Akhter and Alan R. Dutton
assisted by Joong H. Kim and Lehar M. Brion

Final Contract Report

Prepared for

Texas Low-Level Radioactive Waste Disposal Authority
under Interagency Contract Number IAC (90-91)0268

by

Bureau of Economic Geology
W. L. Fisher, Director
The University of Texas at Austin
Austin, Texas 78713

April 1990

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## Figures

## INTRODUCTION

Another method evaluated in this study at the request of the Texas Low-Level Radioactive Waste Disposal Authority is based on procedures developed by the Federal Emergency Management Agency (FEMA) (1985) to estimate flood height in the lower reaches of active alluvial fans. The analysis detailed here shows that use of the FEMA (1985) alluvial fan methodology violates the geologic and geomorphologic evidence available for the study area and also predicts implausible characteristics of surface-water runoff on the study area.

The FEMA (1985) method uses statistical analysis that relates the probability of given discharges at the apex of a fan to the probabilities of a certain depth and velocity of flow occurring at any point on the fan below the apex. The basic assumption is that the area under consideration is an active alluvial fan where surface-water runoff is carried by channels that migrate, randomly avulse, and change course. The flow system is described as a single channel or as multiple channels that exist between the apex of the fan and its extremal boundary. A probability distribution for the peak discharge is required for the analysis. The statistical parameters of this discharge-frequency distribution are used to predict the discharge related to the critical flood height (0.5 ft [0.15 m] for the 100-yr flood category) and to estimate the corresponding arc width of the fan that would be covered by this critical flood height.

## IDENTIFICATION OF FLOW REGIME

The flow regime on an alluvial fan during a major flood event depends on the number of channels created by the flow of water. At peak flow water does not spread evenly over a fan but is confined to channels that carry the water from the apex to the toe of the fan. Three channel patterns encountered during flooding are single, split, and braided (fig. 1). The single channel is located just below the mouth of the canyon in the upper region of the fan and is formed by erosion of the loose material that composes the fan. Length of the single channel region is measured from the mouth of the canyon to the point where the main channel splits; this length varies directly with the ratio of canyon slope to fan slope (FEMA, 1985). The split or multiple channels are formed through repeated bifurcation of channels below the apex of the fan and finally terminate in a braided sheet-flow channel.

The concept of a single equivalent channel is used to compute flood depths. The computed depth of water flow on alluvial fans is the depth of flow (depth of channel) that carries a given discharge to the toe of the fan surface. Water depths between 0.5 and 1.0 ft (0.15 and 0.3 m) depth are rounded to 1 ft (0.3 m), which is a FEMA criterion for delineating a flood-zone boundary.

The length of the single channel region is predicted from site-specific data on canyon and fan slope (fig. 2). The ratio of canyon slope to fan slope is 2.5, determined from a topographic map of the study area, which indicates that no single channel region is present on the site. Therefore, the procedure for a multiple channel region was applied for determination of flood height.

## DETERMINATION OF FLOOD DISCHARGE-FREQUENCY DISTRIBUTION

A flood discharge-frequency distribution is required to determine the discharge at the apex of the alluvial fan. The guidelines for determining flood flow frequency require the application of Log-Pearson Type III analyses (Riggs and others, 1968; U.S. Department of Interior, 1982). Because data for those analyses were not available for the site, flows of various recurrence intervals were computed from HEC-1, and the following synthetic parameters of a Log-Pearson Type III discharge distribution were estimated.

1. $Q_{.01}$, $Q_{.10}$, and $Q_{.50}$, discharges with 0.01, 0.10, and 0.50 exceedence probabilities, respectively:

$$Q_{.01} = 3570 \text{ cfs}, Q_{.10} = 2706 \text{ cfs}, Q_{.50} = 941 \text{ cfs}. \quad (1)$$

2. skew coefficient, G:

$$G = -2.50 + 3.12\,[\log(Q_{.01}/Q_{.10})/\log(Q_{.10}/Q_{.50})] \quad (2)$$
$$= -1.682.$$

3. standard deviation, S:

$$S = [\log(Q_{.01}/Q_{.50})/(K_{.01}-K_{.50})] \quad (3)$$
$$= 0.654.$$

4. mean, X:

$$X = \log(Q_{.50}) - K_{.50}\,S \quad (4)$$
$$= 2.80.$$

For Pearson Type III exceedence probabilities of 0.01 and 0.50 and skew coefficient G, $K_{.01}$ and $K_{.50}$ are frequency factors (number of standard deviations above and below the mean). The values of $K_{.01}$ of 1.151 and $K_{.50}$ of 0.265 were obtained from published guidelines (U.S. Department of the Interior, 1982).

Because the skew coefficient was not zero, the following transformation variables were computed:

$$m = X - 2S/G = 3.578 \quad (5)$$

$$\alpha = 2/GS = -1.819 \quad (6)$$

$$\lambda = 4/G^2 = 1.416 \quad (7)$$

$$a = \alpha - 0.92 = -2.739. \quad (8)$$

The transformation constant was computed as

$$C = (\alpha/a)\,\lambda\,\exp(0.92m) = 25.29. \quad (9)$$

The Log-Pearson Type III parameters (equations 2-4) were transformed using the variables computed above according to the following equations:

$$Z = m + \lambda/a = 3.061 \quad (10)$$

$$S_z^2 = \lambda/a^2 = 0.189 \quad (11)$$

$$S_z = 0.434 \quad (12)$$

$$G_z = 2/\lambda^{1/2} = 1.681. \quad (13)$$

## DETERMINATION OF DISCHARGE FOR 0.5-FT (0.15-M) FLOOD DEPTH

Applying the procedure for a multiple channel region and using a fan slope ($S_f$) of 0.013 and a Manning's coefficient (n) of 0.04, the discharge Q (cfs) that corresponds to the depth of flow (D) equal to 0.5 ft (0.15 m) was calculated by iteratively solving the following equation:

$$D = 0.0917\ n^{0.6}\ S_f^{-0.3}\ Q^{0.36} + 0.001426\ n^{-1.2}\ S_f^{0.6}\ Q^{0.48} \quad (14)$$

For D of 0.5 ft (0.15 m), Q is calculated to be 380 cfs.

## DETERMINATION OF FAN WIDTH AT 0.5-FT (0.15-M) DEPTH BOUNDARY

The Log-Pearson Type III frequency factor (K) was computed for the discharge that corresponds to 0.5-ft (0.15-m) depth zone boundary using equation 15:

$$K = (\log Q - Z)/S_z = (\log 380 - 3.061)/0.434 = -1.109. \quad (15)$$

The probability of occurrence (P) of the discharge for a flood depth of 0.5 ft (0.15 m) is greater than:

$$P\ (Q > 380) = P\ (K > -1.109) = 0.866. \quad (16)$$

The fan arc width is computed as:

where A is the avulsion coefficient (factor accounting for the possibility of channel switching during major floods on active alluvial fans) and C is the transformation constant (equation 9). The constant 3610 is used for multiple channel regions, and the value of 1.5 for avulsion coefficient is recommended in absence of empirical data (FEMA, 1985). Assuming a constant expansion angle, the 100-yr flood based on equation 17 would reach a fan arc width of 118,600 ft (36,160 m).

## DISCUSSION

Disadvantages of the alluvial fan method include its insensitivity to topographic features of the study area or hydraulic storage in existing channels. Further, the arbitrary designation of the fan apex and expansion angle unduly affects this method. Figure 3 shows the area predicted by this method to be under a 100-yr floodplain. The 118,600 ft (36,160 m) arc width of the fan implies flooding far downstream of the study area, beyond the wide reaches of the interarroyo plain between Camp Rice and Alamo arroyos, over the steep topographic relief within the arroyos, and across the Rio Grande valley. This result clearly is implausible. There is no sediment record of such an extensive flood with a return frequency of 0.01 or less. Moreover, the study area is an alluvial plain or slope, not a fan (T. C. Gustavson, personal communication, 1989). Misapplication of the alluvial fan method to this low-relief setting probably accounts for the implausible conclusion.

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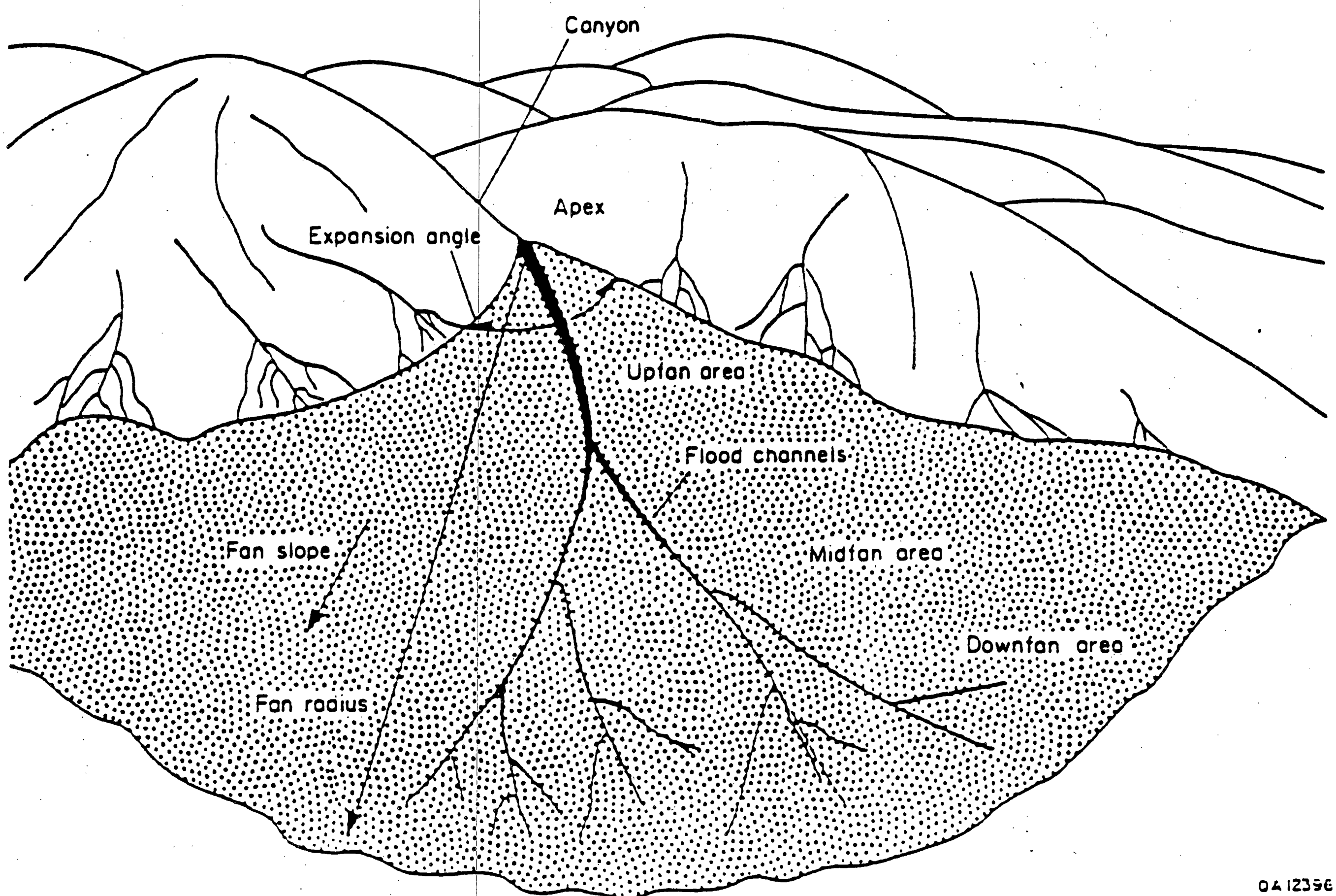


Figure 1. Alluvial fan characteristics.

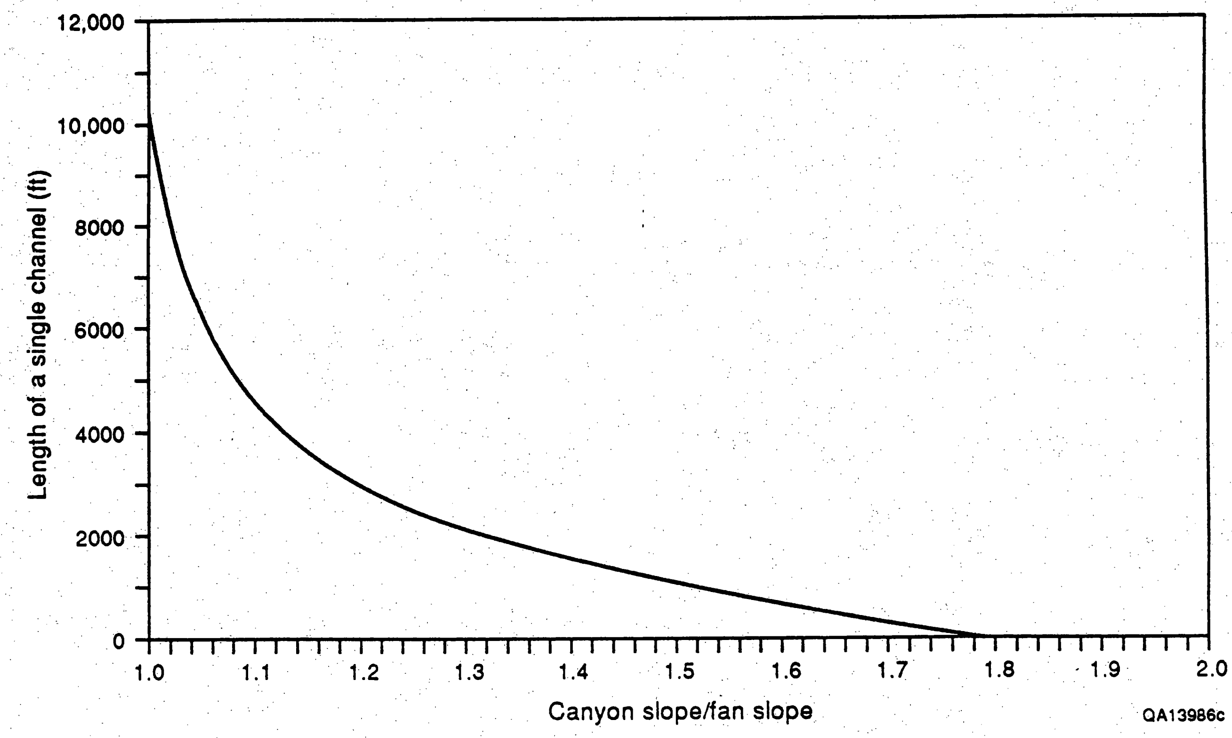


Figure 2. Relation between length of a single channel and ratio of canyon slope to fan slope. From FEMA (1985).

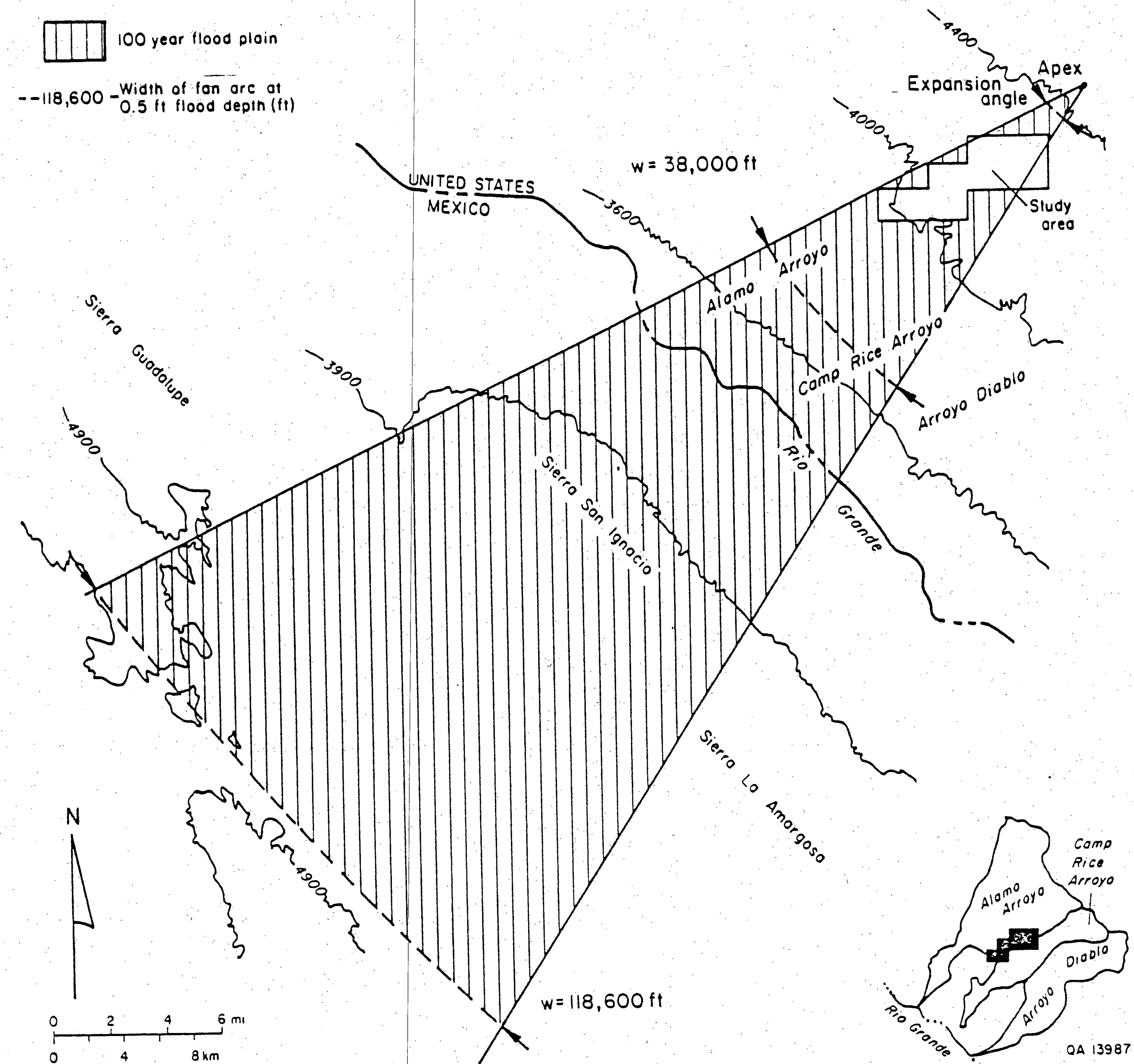


Figure 3. Flood profile for alluvial fan model, northern part of the study area.

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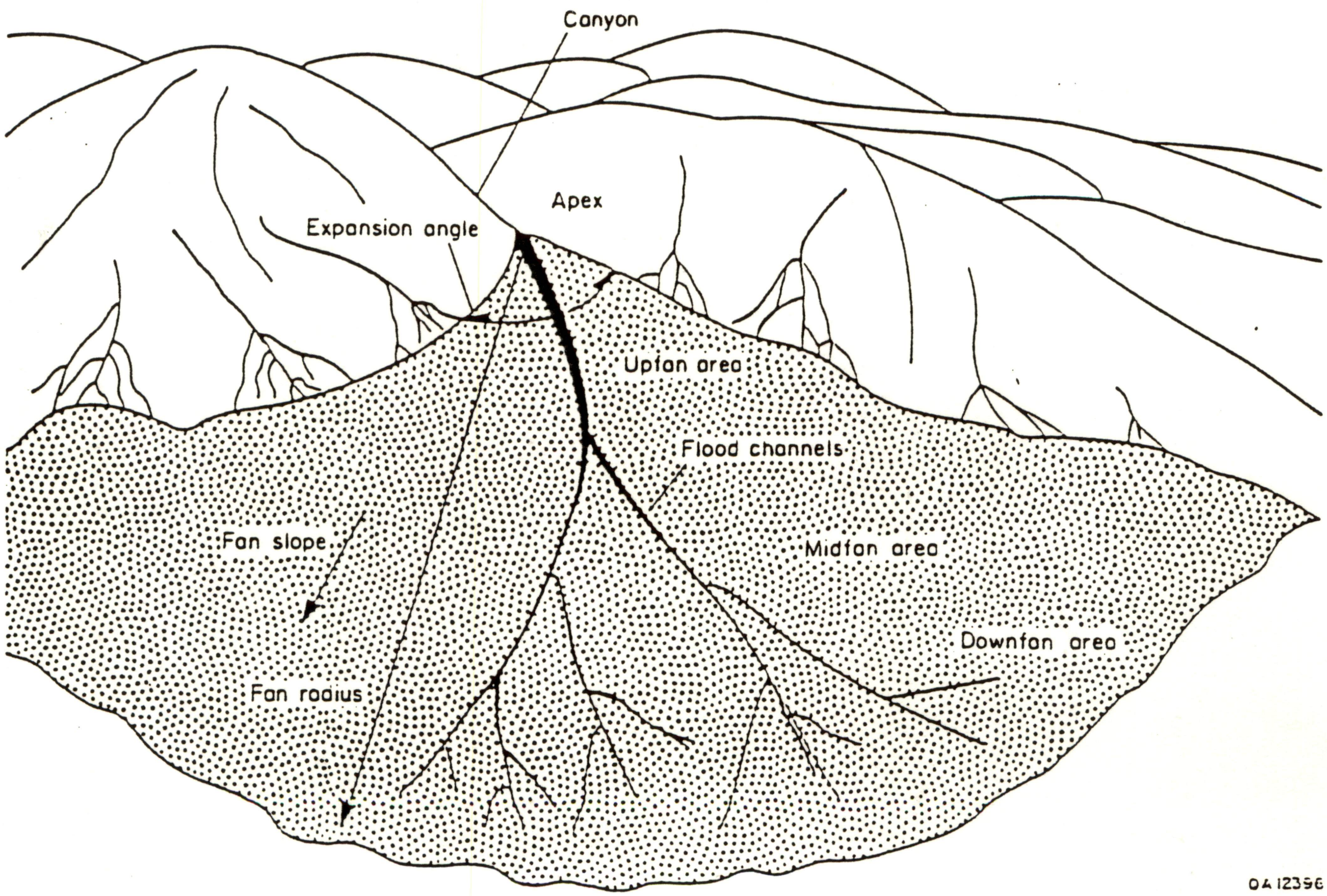


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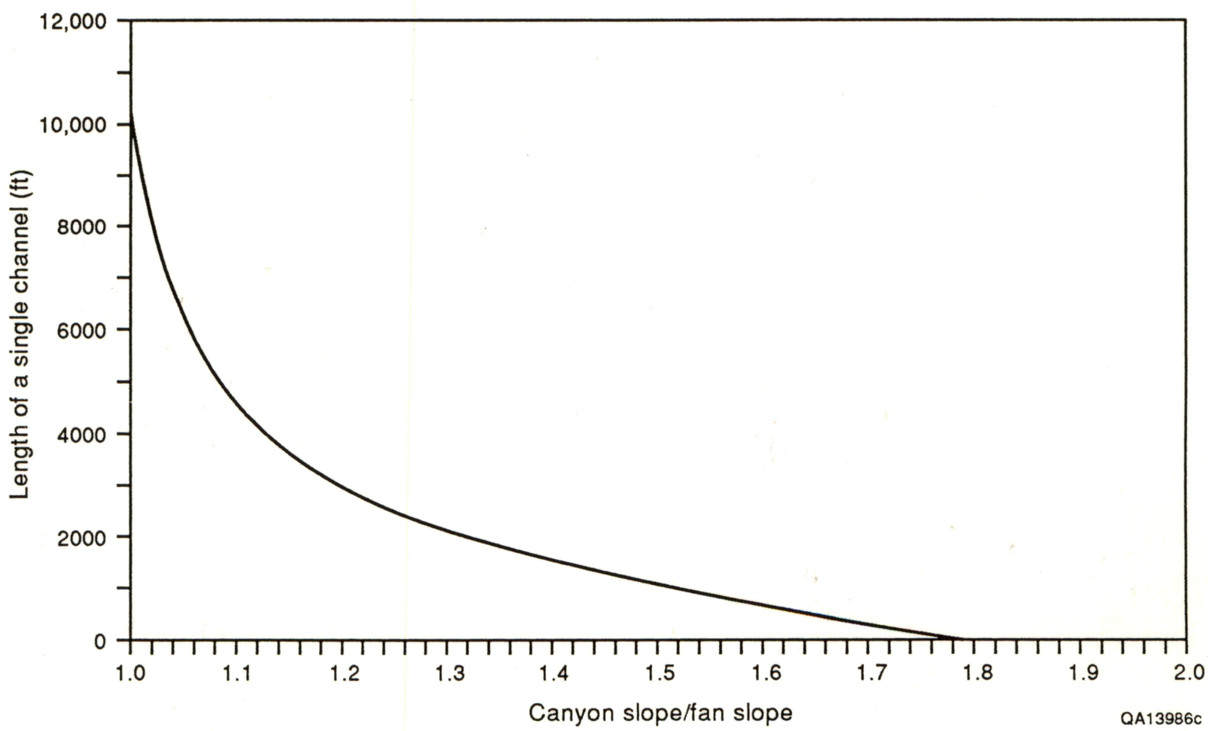


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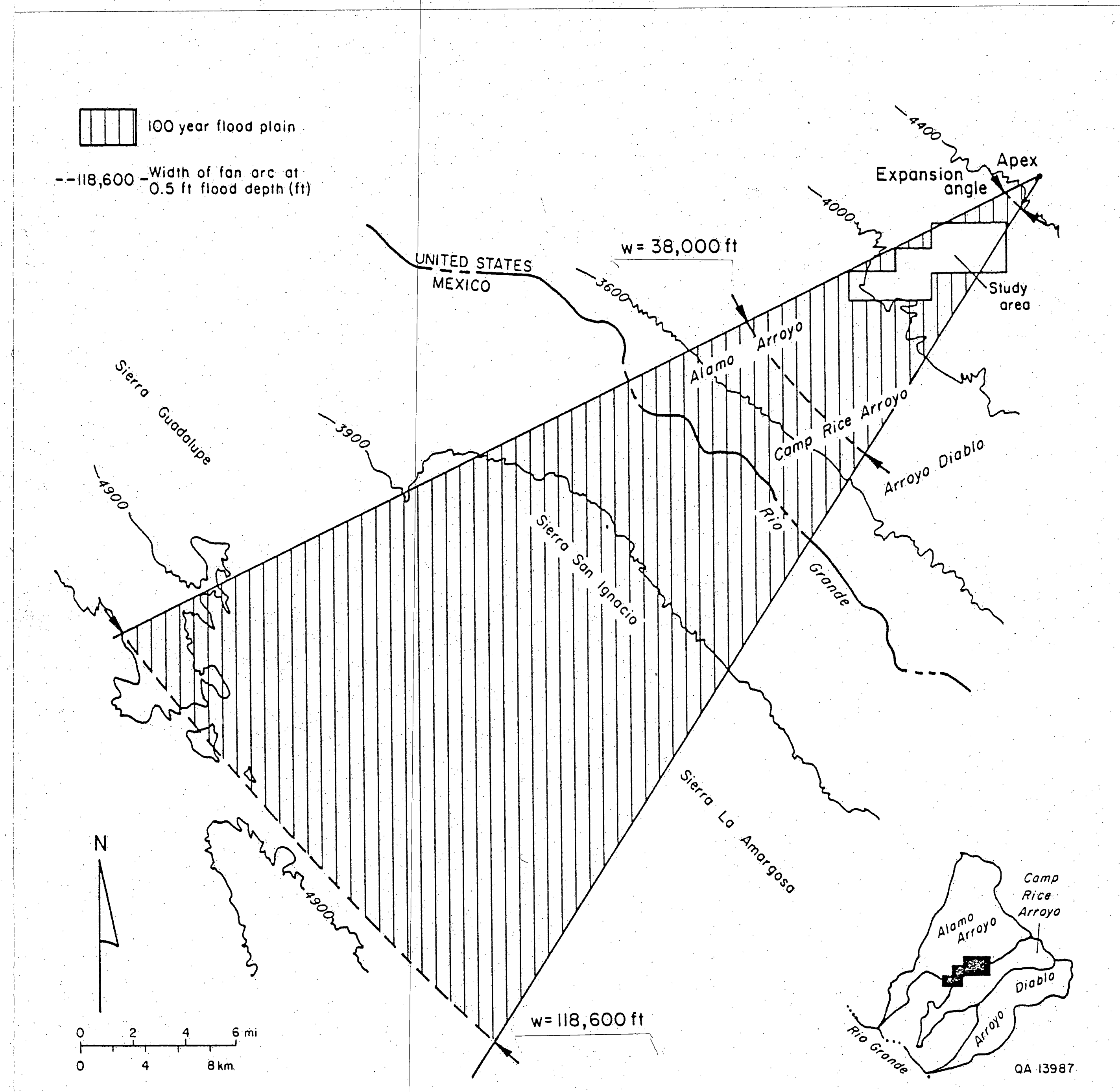


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