Historical and Paleoflood Analyses for Probabilistic Flood Hazard Assessments—Approaches and Review Guidelines

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U.S. Department of the Interior
U.S. Geological Survey

Project Funded by the U.S. Nuclear Regulatory Commission

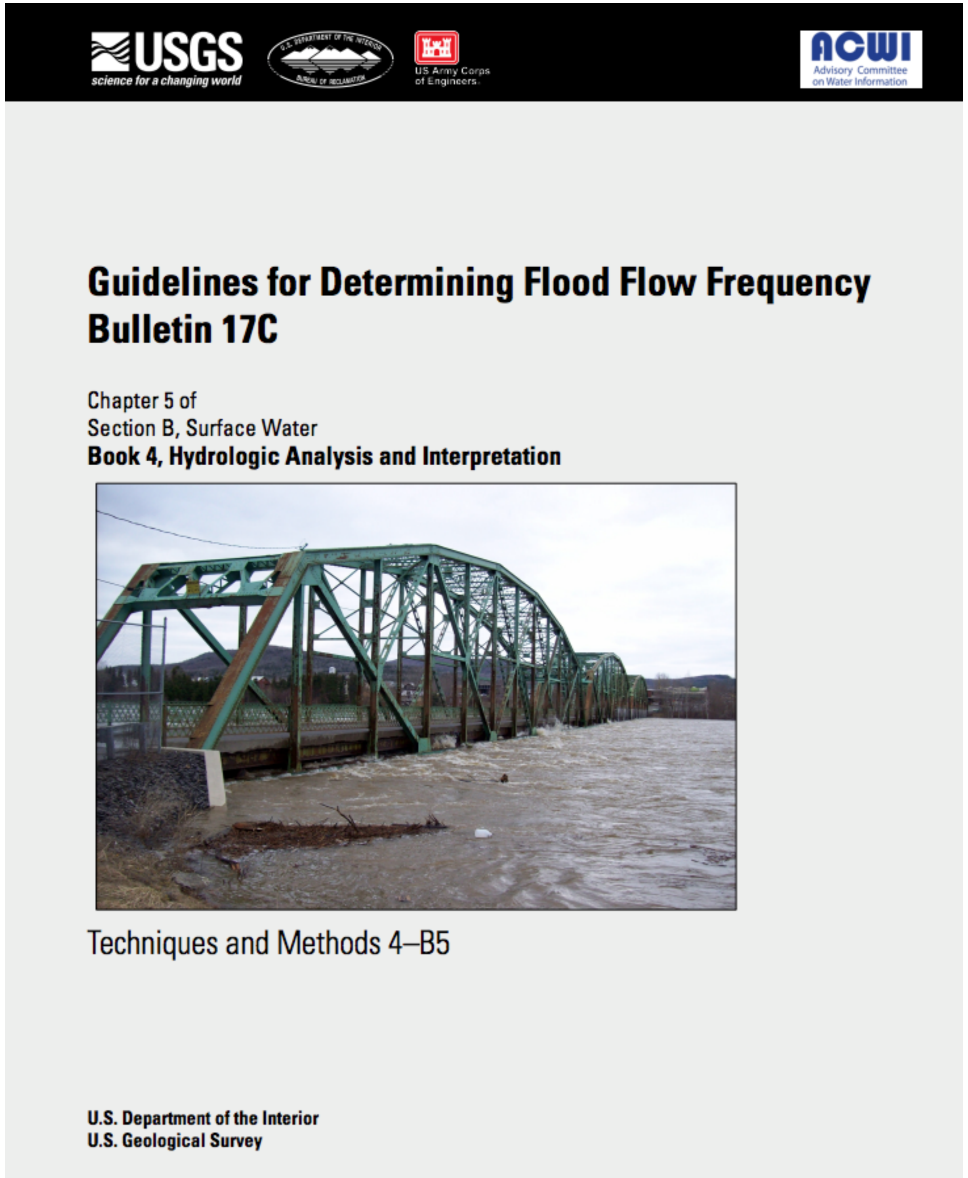
- Will be published as a USGS Techniques and Methods Report.
- Has had extensive review by
  - NRC staff,
  - academic experts in flood geomorphology and tree rings, and
  - a Surface-Water Specialist in the USGS Hydrologic Networks Branch
- Currently being edited
- Hope to have it published by end of 2021

Motivation for Report and Related Workshop

- Paleoflood hydrology studies are an increasingly import tool for design and safer operation of critical infrastructure.
  - Extending the effective flood record
  - Informing estimates of the magnitude and frequency of flooding hazards
- Standards of practice for conducting and reviewing such studies are lacking.
  - Inhibits effective use in regulatory decision making

Bulletin 17C

Federal agencies are requested to use these Guidelines in all planning activities involving water and related land resources. State, local, and private organizations are encouraged to use these Guidelines to assure uniformity in the flood frequency estimates that all agencies concerned with flood risk should use for Federal planning decisions.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US Army Corps of Engineers
ACWI Advisory Committee on Water Information

Guidelines for Determining Flood Flow Frequency Bulletin 17C

Chapter 5 of
Section B, Surface Water
Book 4, Hydrologic Analysis and Interpretation

Techniques and Methods 4–B5

U.S. Department of the Interior
U.S. Geological Survey

England and others, 2018

ENGLAND AND OTHERS, 2018, p. 125

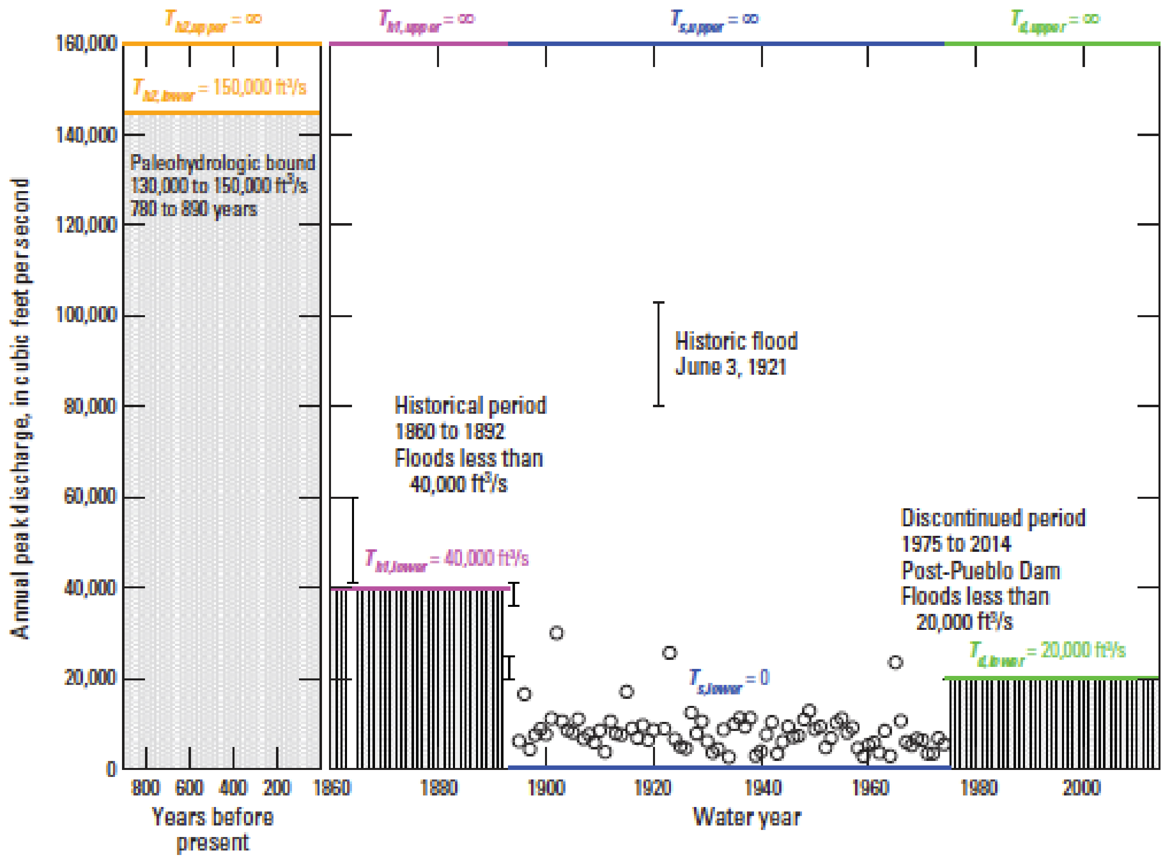
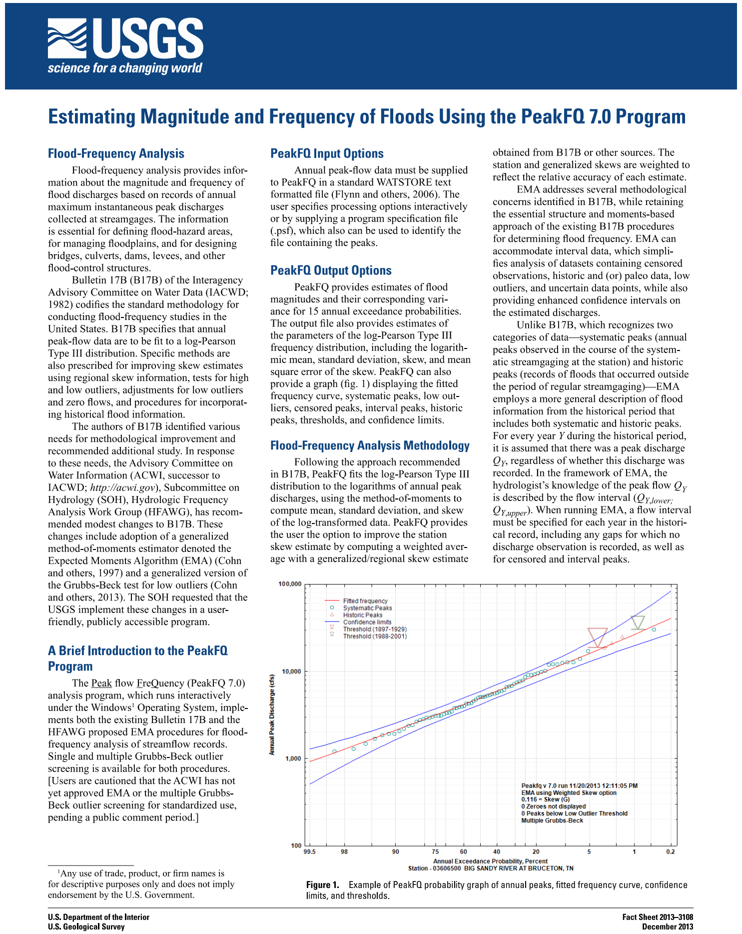


Figure 10–8. Graph showing peak discharge, historical and paleoflood estimates, Arkansas River at Pueblo State Park. A scale break is used to separate the gage and historical data from the longer paleoflood record. Flood intervals are shown as black vertical bars with caps that represent lower and upper flow estimates, including unobserved estimates in the historical period and historical floods in 1864, 1893, 1894 and 1921. The gray shaded areas represents floods of unknown magnitude less than the perception thresholds for the paleoflood period $T_{h2,lower}$, the historical period $T_{h1,lower}$, and the discontinued period $T_{d,lower}$. Perception threshold ranges in cubic feet per second (ft^3/s) are shown as orange lines for the paleoflood period, magenta lines for the historical period, blue lines for the systematic period, and green lines for the discontinued period.

Software



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Estimating Magnitude and Frequency of Floods Using the PeakFQ 7.0 Program

Flood-Frequency Analysis

Flood-frequency analysis provides information about the magnitude and frequency of flood discharges based on records of annual maximum instantaneous peak discharges collected at streamgages. The information is essential for defining flood-hazard areas, for managing floodplains, and for designing bridges, culverts, dams, levees, and other flood-control structures.

Bulletin 17B (B17B) of the Interagency Advisory Committee on Water Data (IACWD; 1982) codifies the standard methodology for conducting flood-frequency studies in the United States. B17B specifies that annual peak-flow data are to be fit to a log-Pearson Type III distribution. Specific methods are also prescribed for improving skew estimates using regional skew information, tests for high and low outliers, adjustments for low outliers and zero flows, and procedures for incorporating historical flood information.

The authors of B17B identified various needs for methodological improvement and recommended additional study. In response to these needs, the Advisory Committee on Water Information (ACWI, successor to IACWD; *http://acwi.gov*), Subcommittee on Hydrology (SOH), Hydrologic Frequency Analysis Work Group (HFAWG), has recommended modest changes to B17B. These changes include adoption of a generalized method-of-moments estimator denoted the Expected Moments Algorithm (EMA) (Cohn and others, 1997) and a generalized version of the Grubbs-Beck test for low outliers (Cohn and others, 2013). The SOH requested that the USGS implement these changes in a user-friendly, publicly accessible program.

A Brief Introduction to the PeakFQ Program

The Peak flow FreQuency (PeakFQ 7.0) analysis program, which runs interactively under the Windows[1] Operating System, implements both the existing Bulletin 17B and the HFAWG proposed EMA procedures for flood-frequency analysis of streamflow records. Single and multiple Grubbs-Beck outlier screening is available for both procedures. [Users are cautioned that the ACWI has not yet approved EMA or the multiple Grubbs-Beck outlier screening for standardized use, pending a public comment period.]

PeakFQ Input Options

Annual peak-flow data must be supplied to PeakFQ in a standard WATSTORE text formatted file (Flynn and others, 2006). The user specifies processing options interactively or by supplying a program specification file (.psf), which also can be used to identify the file containing the peaks.

PeakFQ Output Options

PeakFQ provides estimates of flood magnitudes and their corresponding variance for 15 annual exceedance probabilities. The output file also provides estimates of the parameters of the log-Pearson Type III frequency distribution, including the logarithmic mean, standard deviation, skew, and mean square error of the skew. PeakFQ can also provide a graph (fig. 1) displaying the fitted frequency curve, systematic peaks, low outliers, censored peaks, interval peaks, historic peaks, thresholds, and confidence limits.

Flood-Frequency Analysis Methodology

Following the approach recommended in B17B, PeakFQ fits the log-Pearson Type III distribution to the logarithms of annual peak discharges, using the method-of-moments to compute mean, standard deviation, and skew of the log-transformed data. PeakFQ provides the user the option to improve the station skew estimate by computing a weighted average with a generalized/regional skew estimate obtained from B17B or other sources. The station and generalized skews are weighted to reflect the relative accuracy of each estimate.

EMA addresses several methodological concerns identified in B17B, while retaining the essential structure and moments-based approach of the existing B17B procedures for determining flood frequency. EMA can accommodate interval data, which simplifies analysis of datasets containing censored observations, historic and (or) paleo data, low outliers, and uncertain data points, while also providing enhanced confidence intervals on the estimated discharges.

Unlike B17B, which recognizes two categories of data—systematic peaks (annual peaks observed in the course of the systematic streamgaging at the station) and historic peaks (records of floods that occurred outside the period of regular streamgaging)—EMA employs a more general description of flood information from the historical period that includes both systematic and historic peaks. For every year Y during the historical period, it is assumed that there was a peak discharge Q_Y, regardless of whether this discharge was recorded. In the framework of EMA, the hydrologist's knowledge of the peak flow Q_Y is described by the flow interval ($Q_{Y,lower}$; $Q_{Y,upper}$). When running EMA, a flow interval must be specified for each year in the historical record, including any gaps for which no discharge observation is recorded, as well as for censored and interval peaks.

Figure 1. Example of PeakFQ probability graph of annual peaks, fitted frequency curve, confidence limits, and thresholds.

[1]Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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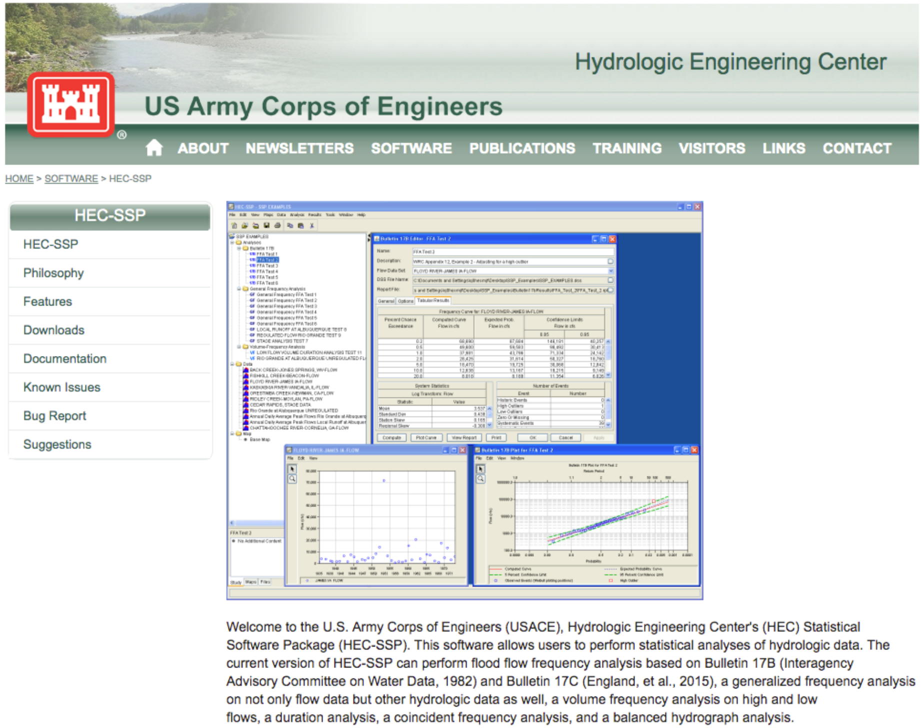
Fact Sheet 2013–3108
December 2013

- Software incorporates ability to use perception thresholds and interval estimates.
- Can account for the inherent greater uncertainty in historical and paleofloods.



Veilleux and others, 2014

https://www.hec.usace.army.mil/software/hec-ssp/

	Documentation Type	Description
Paleoflood Study Attributes	Site Information	Level 1: location and description of study area, map of area, simplistic description of hydrology, geomorphology and geology of study area; stream/river length, slope, sinuosity; location (survey or GPS), photo or site sketch, comments. If using previously published regional paleoflood information, not all information may be available. Level 2: Basin level: location and description of study area, maps, lidar, existing inundation maps/models, land use maps, soil maps, general description of hydrology, geomorphology and geology of study Reach Level: reach location, photos, stream information (width, confined or unconfined, slope, etc.), general description of local geomorphology and geology Site level: location data, surveying of landmark to link to lidar or aerial photography, aspect, land cover, photos, site sketch or annotated map, comments or observations Level 3: similar to Level 2, except for multiple basins and sites. Documentation may need to be standardized across many field teams and simplified for tabulation.

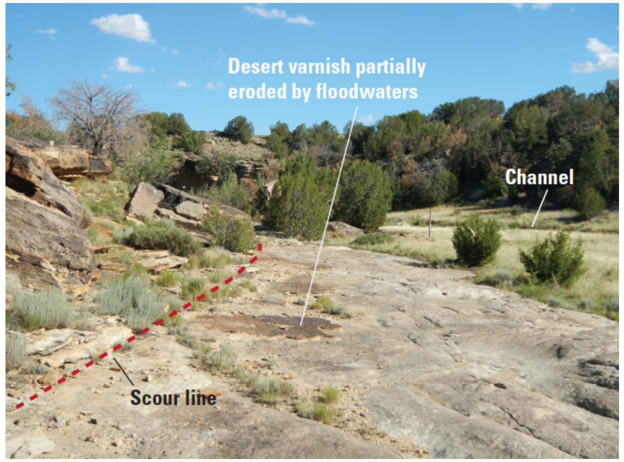
	Documentation Type	Description
Paleoflood Study Attributes	Stratigraphy	Level 1: Study area: Photos and maps of site locations, major landmarks, etc. Sites: locations, schematic diagrams, photos, number of units in the stratigraphic sequence, method used to expose stratigraphy; Stratigraphic descriptions for each unit: thickness, color, texture grainsize estimate, degree of sorting, moisture content, amount of organic material, type of fluvial structures (such as laminations or cross bedding), dip, degree of bioturbation, nature of contact between the units. Level 2 and 3: Similar to Level 1 but includes more sites and basins (Level 3). May include samples for grain size or geochemical analyses.

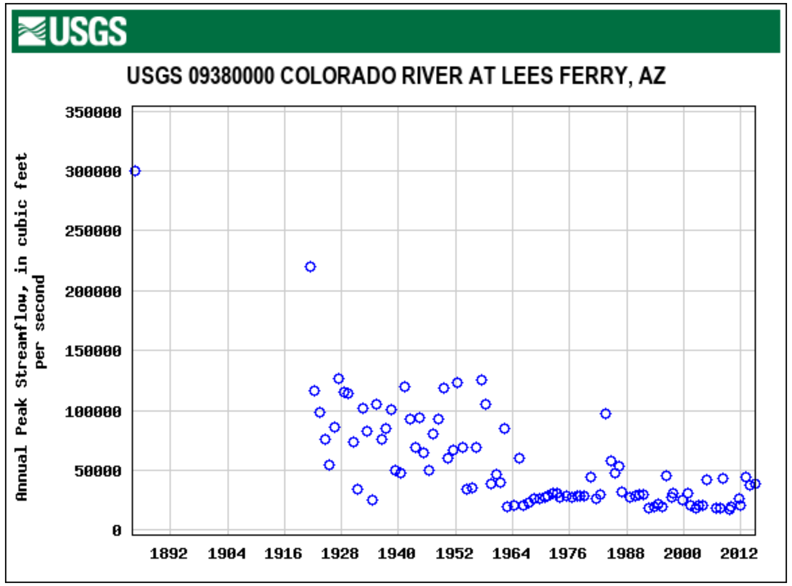
	Documentation Type	Description
Paleoflood Study Attributes	Botanical	Level 1: *Trees:* species, condition, record of locations, scar location and height; may include limited cores or slabs at chest height, observations and locations for recent HWMs, notes Level 2 and 3: *Trees:* species, condition, sketches, photos or annotated maps and locations of geomorphic and geographic positions (distance from trees to locations with respect to the thalweg, channel, bank, floodplain; straight reaches, inside or outside bend; exposure), equipment and precision for distances and elevation, description of geological characteristics, observations and locations for recent HWMs, notes *Indicator:* scar or damage height, description, description of observed debris (boulders, woody), skeleton plots; tilt description, aspect, angle to river; wedge, cross-section or core location and elevation, photo, equipment used, comments *Burial study information:* sediment depth, description, excavation method and details, tree species, condition, slab locations, elevations and methods, method to link information with stratigraphic exposure, stratigraphic information from exposure as above

Paleoflood Study Attributes	Documentation Type	Description
	Geochronology	All Levels: All samples: Dating method, sample location, photo, schematic diagram with sample location in exposure or core, stratigraphic unit; depth below surface, material, key observations and comments, lab results, uncertainty Soil Development: note characteristic soils and structures similar to nearby quantitatively dated studies, record: trimlines, soil characteristics, desert pavement, physical weathering of rocks and terraces, and vegetation. Dating anthropogenic evidence, unusual geologic evidence. Tree rings: preparation methods, equipment, techniques, skeleton plots, criteria for, description of and measurements of growth anomalies, method of statistical evaluation of cross-dating with other samples/trees, software version, inputs and outputs, photographs, uncertainty estimates Radiocarbon: organic material description, photo, sample location and sampling collection method and storage, dating technique (AMS or conventional), results, corrections, uncertainties

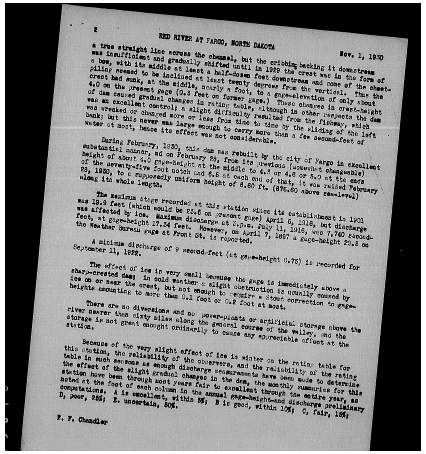
Also Address Levels of Review In These Areas

- Source Information for Systematic, Historic and Paleoflood Data
- Flow Estimation Methods
- Flood-Frequency (Hydraulic Hazard Analysis) Methods
- Uncertainty and Non-Stationarity Records and Methods
- Comparison with Other Analyses





Cass County Historical Society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RED RIVER AT FARGO, NORTH DAKOTA

Nov. 1, 1930

a true straight line across the channel, but the cribbing backing it downstream was insufficient and gradually shifted until in 1929 the crest was in the form of a bow, with its middle at least a half-dozen feet downstream and some of the sheet-piling seemed to be inclined at least twenty degrees from the vertical. Thus the crest had sunk, at the middle, nearly a foot, to a gage-elevation of only about 4.0 on the present gage (0.3 feet on former gage.) These changes in crest-height of dam caused gradual changes in rating table, although in other respects the dam was an excellent control; a slight difficulty resulted from the fishway, which was wrecked or changed more or less from time to time by the sliding of the left bank; but this never was large enough to carry more than a few second-feet of water at most, hence its effect was not considerable.

During February, 1930, this dam was rebuilt by the city of Fargo in excellent substantial manner, ad on February 28, from its previous (somewhat changeable) height of about 4.0 gage-height at the middle to 4.3 or 4.6 or 5.0 at the ends of the seventy-five foot notch and 6.5 at each end of that, it was raised February 28, 1930, to a supposedly uniform height of 6.60 ft. (876.60 above sea-level) along its whole length.

The maximum stage recorded at this station since its establishment in 1901 was 19.9 feet (which would be 23.6 on present gage) April 6, 1916, but discharge was affected by ice. Maximum discharge at 3.p.m. July 11, 1916, was 7,740 second-feet, at gage-height 17.34 feet. However, on April 7, 1897 a gage-height 29.3 on the Weather Bureau gage at Front St. is reported.

A minimum discharge of 9 second-feet (at gage-height 0.75) is recorded for September 11, 1922.

The effect of ice is very small because the gage is immediately above a sharp-crested dam; in cold weather a slight obstruction is usually caused by ice on or near the crest, but not enough to require a Stout correction to gage-heights amounting to more than 0.1 foot or 0.2 foot at most.

There are no diversions and no power-plants or artificial storage above the river nearer than sixty miles along the general course of the valley, and the storage is not great enought ordinarily to cause any appreciable affect at the station.

Because of the very slight effect of ice in winter on the rating table for this station, the reliability of the observers, and the reliability of the rating table in such seasons as enough discharge measurements have been made to determine the effect of the slight gradual changes in the dam, the monthly summaries for this station have been through most years fair to excellent through the entire year, as noted at the foot of each column in the annual gage-height-and discharge preliminary computations. A is excellent, within 5%; B is good, within 10%; C, fair, 15%; D, poor, 25%; E. uncertain, 50%.

F. F. Chandler

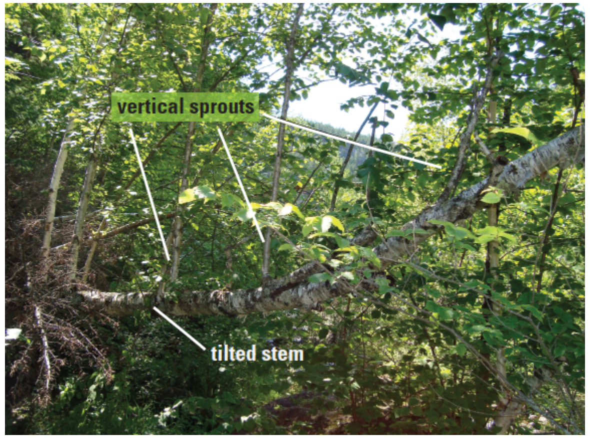

Figure Examples

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