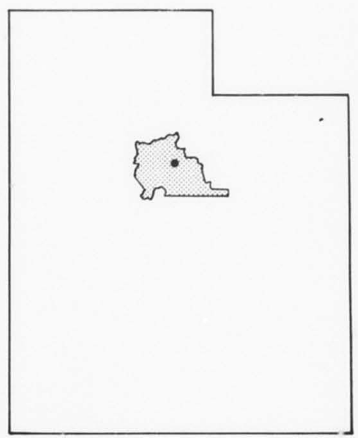
1988

# Flood Insurance Study, City of Provo, Utah, Utah County

Federal Emergency Management Agency

# FLOOD INSURANCE STUDY

## CITY OF PROVO, UTAH
### UTAH COUNTY



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Federal Emergency Management Agency

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NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

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FLOOD INSURANCE STUDY
CITY OF PROVO, UTAH COUNTY, UTAH

# 1.0 INTRODUCTION

## 1.1 Purpose of Study

This Flood Insurance Study revises and updates a previous Flood Insurance Study/Flood Insurance Rate Map for the City of Provo Utah. This information will be used by the City to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP). The information will also be used by local and regional planners to further promote sound land use and floodplain development.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence; and the State (or other jurisdictional agency) will be able to explain them.

## 1.2 Authority and Acknowledgments

The sources of authority for this Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses for the original study were performed by the U.S. Bureau of Reclamation (USBR) for the Federal Emergency Management Agency (FEMA), under Inter-Agency Agreement No. IAA-H-12-76, Project Order No. 2. This work, which was completed in June 1977, covered all significant flooding sources affecting the City of Provo. Further analyses were performed by the USBR under Inter-Agency Agreement No. IAA-H-6-77, Project Order No. 4, for the Provo River within areas annexed into the city since the original study.

The hydrologic and hydraulic analyses for this study were performed by Rollins, Brown and Gunnell, Inc., for FEMA, under Contract No. EMW-84-C-1628. This work was completed in May 1986.

## 1.3 Coordination

On April 12, 1976, community information was obtained and flooding sources requiring detailed study in the original study were identified at an initial meeting attended by representatives of the City of Provo, FEMA, and the study contractor.

The hydrologic analysis was discussed and flood profiles were coordinated with those developed by the U.S. Army Corps of Engineers (COE), Sacramento District, during the course of study.



Additional coordination and contacts during this study included exchange with the Provo City Engineer, Provo City Planning Commission, Utah County Flood Action Committee, COE, U.S. Forest Service (USFS), U.S. Geological Survey (USGS), interviews with local residents, and newspaper accounts concerning flood problems and past flood events.

On December 13, 1977, the results of the study were reviewed at a final coordination meeting attended by representatives of the City of Provo, FEMA, and the study contractor. No changes or revisions were required as a result of that meeting.

Community information was obtained and flooding sources requiring detailed analyses for the revised study were identified at an initial consultation coordination officer (CCO) meeting attended by representatives of the City of Provo, FEMA, and the study contractor on April 19, 1984.

Requests for pertinent information were made to the City of Provo, USFS, COE, U.S. Soil Conservation Service (SCS), USGS, Utah Division of Water Resources, and Utah Water Research Laboratory.

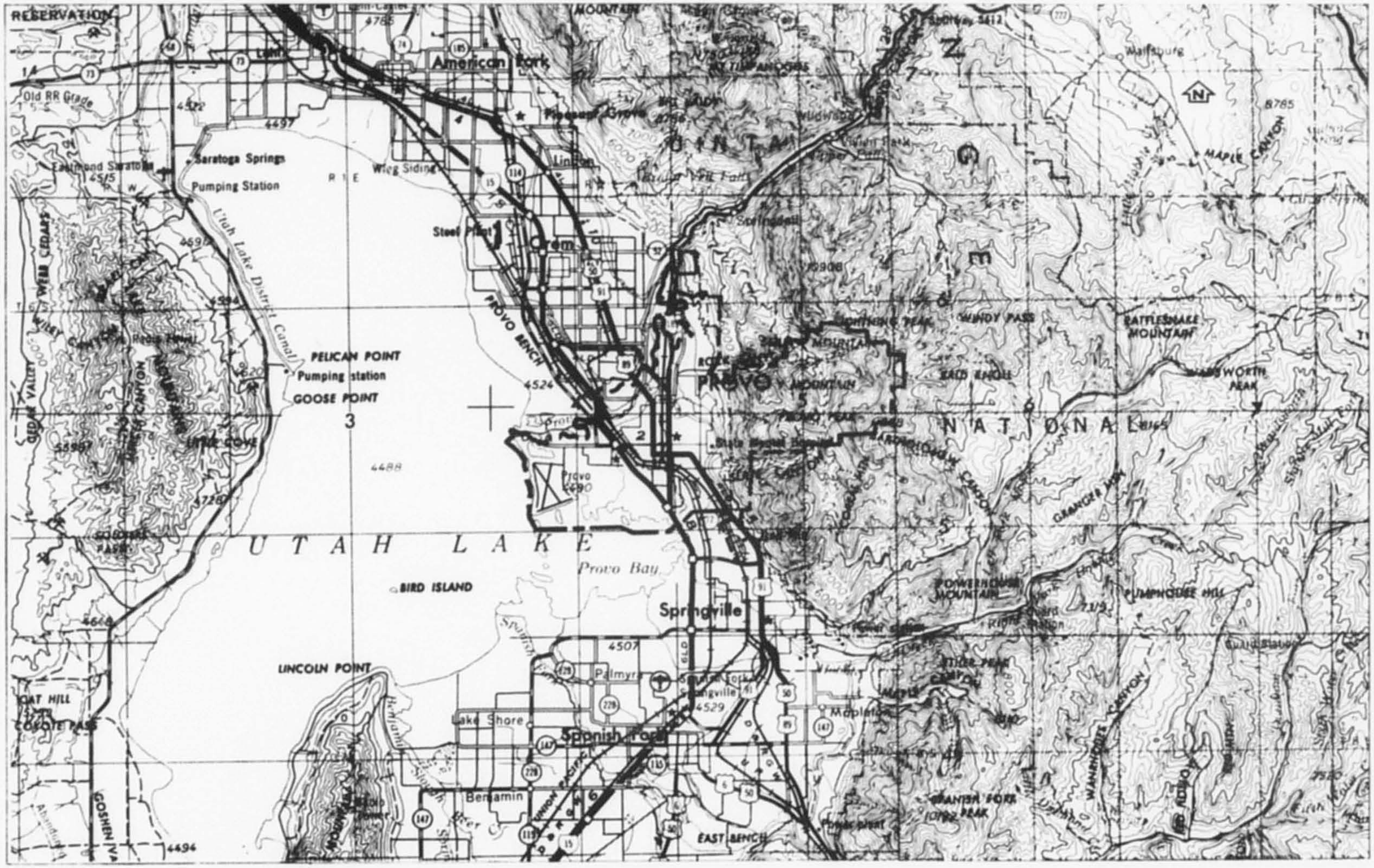
Results of the hydrologic analyses were sent to the City of Provo, the State Division of Comprehensive Emergency Management, and the COE for review and comment. The results of the study were reviewed at an intermediate coordination meeting with personnel from the City of Provo on June 12, 1986. No changes or revisions were required as a result of this meeting.

# 2.0 AREA STUDIED

## 2.1 Scope of Study

This Flood Insurance Study covers the incorporated areas of the City of Provo, Utah County, Utah. The area of study is shown on the Vicinity Map (Figure 1).

Flooding caused by the overflow of the Provo River and high stages of Utah Lake were studied by detailed methods. The Provo River was studied from the confluence with Utah Lake upstream to a point approximately 0.3 mile upstream of the 800 North Road bridge, a distance of 10.1 miles. Slate Canyon, Rock Canyon, Little Rock Canyon, and small Wasatch Mountain Front drainages along the eastern corporate limits of Provo were also studied by detailed methods. These areas were studied in 1978, and this restudy of these areas resulted in changes in all areas except the 100-year level of Utah Lake. Two additional small frontal drainages, Slide Canyon and Buckley Draw Creek, were also studied by detailed methods. Other small mountain front drainages that enter Provo along the eastern corporate limits were not studied because flood discharges from these drainages do not cause significant flood damage within the study areas.




| FIGURE 1 | FEDERAL EMERGENCY MANAGEMENT AGENCY<br>**CITY OF PROVO, UT**<br>**(UTAH CO.)** | APPROXIMATE SCALE<br>4 0 4 8 12 MILES<br>**VICINITY MAP** |
|---|---|---|

The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development or proposed construction through May 1990.

Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and the City of Provo.

## 2.2 Community Description

The City of Provo is located approximately 46 miles south of Salt Lake City, in central Utah, and has a population estimated at 80,500 (Reference 1). Provo is now the commercial, industrial, governmental, and cultural center in Utah south of Salt Lake City.

The Provo River is a perennial stream that originates in the headwater areas of the Uinta Mountain Range in northern Utah and flows approximately 60 miles before emptying into Utah Lake at Provo. The Provo River, the largest single tributary to Utah Lake, flows south from the mouth of Provo Canyon to the northern corporate limits, through the city, and then southwesterly to drain into Utah Lake. The Provo River basin rises from an elevation of about 4,480 feet at the mouth of the Provo River to an elevation of 11,000 feet in the headwater areas.

Slate Canyon and Rock Canyon Creeks, which are small intermittent streams, and Little Rock Canyon, Slide Canyon, and Buckley Draw Creeks, small ephemeral streams, enter the Provo Beach areas at the eastern corporate limits.

Utah Lake, a shallow water body with a surface area of approximately 150 square miles, lies along the western corporate limits of Provo. Provo Bay, a bay area of Utah Lake, borders the city on the south.

Commercial areas and older residential structures are located along the Provo River. The upper reaches of the river exist in a confined floodplain, whereas the lower area of commercial and residential development is located on a broad floodplain that slopes gently away from the main channel toward Provo Bay and Utah Lake. Developing residential areas which are located chiefly on the eastern benchland of Provo are susceptible to flooding from mountain front drainages. Residential and commercial development is also occurring along the land adjacent to Utah Lake, most of which is protected by dikes and Provo River levees.

Average annual precipitation in the basin ranges from approximately 16 inches in the valley floor area to approximately 40 inches in the high headwater areas (Reference 2). The climate ranges from semiarid in the lower elevation to dry-subhumid in the mountainous areas.



## 2.3 Principal Flood Problems

Low-lying areas of Provo are subject to periodic flooding caused by overflow from the Provo River. The most severe flooding occurs in early spring as a result of snowmelt.

Provo is known to have a history of flooding from the Provo River. The maximum recorded flood peak of 2,520 cubic feet per second (cfs), which was a 50-year event, occurred on May 6, 1952, and was the result of high snowmelt runoff augmented by moderate rains. This flood caused considerable damage to the community. Major and minor flooding also occurred in 1849, 1905, 1912, 1917, 1920, 1921, 1922, 1923, 1957, and 1983. The 1983 flood had a peak snowmelt discharge of 2,420 cfs, and sandbagging was required to keep the river within its banks through the City of Provo.

Flooding from cloudburst storms has occurred in the Provo River Canyon, but floodflows largely dissipate before reaching the study area. Lands adjacent to Utah Lake are subject to frequent flooding from high lake elevations. The most severe floods in the City of Provo occur in the spring as a result of high snowmelt runoff in conjunction with high water levels on Utah Lake.

Shallow flooding caused by a combination of shallow overflow and alluvial fan flow occurs in portions of Provo below the mountain front canyons. Flooding occurs in late spring and summer as a result of intense convective-type storms and/or snowmelt runoffs. The five frontal canyon streams have a history of flooding. Rock Canyon and Slate Canyon Creeks have clearly defined channels which contain floods until they reach detention basins. These in turn dissipate peak floods, which then discharge into or near residential areas.

Little Rock Canyon empties small floodflows into a residential area. These floodflows are aggravated by debris and sediment which obstruct flow in front and inside of culverts and cause the stream to overflow its banks. Slide Canyon and Buckley Draw discharge similarly onto undeveloped alluvial fans.

## 2.4 Flood Protection Measures

The Provo River is a perennial stream with 600 square miles of drainage area in the Uinta Mountains east of Provo. Flows are largely controlled by Deer Creek Dam and Reservoir, which are approximately 12 miles upstream from the study area in Provo Canyon. The reservoir is a storage facility for municipal, industrial, and irrigation water. It has no specified role as flood control storage, but does provide some incidental flood protection to Provo by retaining high snowmelt runoff when the reservoir is not full. Reservoir inflows include flows from the Duchesne Tunnel and Weber-Provo Diversion Canal. These are transmountain diversions that are mechanically controlled and may have flows reduced to alleviate excessive flood inflow conditions.

In 1983 and 1984, Provo made major improvements in a previously discontinuous system of levees along the Provo River. The upgraded levees protect a major portion of Provo from high peak flows of the river, but overflow does occur in a few areas where levees are not constructed. The levees are constructed from compacted earthfill and streambed materials. Provo has established a right-of-way restriction for developing along the riverbanks. During the low flow periods of late summer, portions of the main channel of the Provo River are rehabilitated and cleaned of debris and vegetation to improve channel conditions and streamflow.

Except for a large tract of farmland, Provo is protected from the 100-year flooding of Utah Lake by the recent construction of dikes along Provo's south and west lake borders. Also, a recently completed flood management program on the Jordan River allows for a much increased discharge out of Utah Lake, thereby decreasing peak lake elevation (Reference 3).

Flood damage from Slide Canyon and Buckley Draw is minimal because both have large undeveloped alluvial outwash fans and small floodflows. Flooding from Little Rock Canyon is also minimal because of small flows which can be mostly contained in the streets.

Three debris basins constructed below the mouth of Slate Canyon and one basin below Rock Canyon provide some flood protection. The magnitude of floodflows from these canyons is significantly reduced by the debris basins.

The USFS has treated the land in the upper portions of the Rock Canyon, Little Rock Canyon, and Slate Canyon Creek drainage basins to stabilize slopes and improve surface storage capacities. The area has been treated with contour trenching, gully washes have been plugged, and side slopes have been seeded to increase vegetative cover.

Utah Lake, the Provo River, and the Wasatch Mountain Front drainage basins are included in the planning and design phases of the Central Utah Project, Bonneville Unit, a massive water storage and conveyance system of the USBR, Upper Colorado Region, that will provide flood control benefits and water supply for the Bonneville Basin of Utah.

Jordanelle Dam and Reservoir is to be constructed approximately 15 miles upstream from Deer Creek Reservoir. This facility will be operated to provide increased flood protection from snowmelt runoff in the Provo area.

## 3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study.



Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10, 2, 1, and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term <u>average</u> period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

### 3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

Flood magnitudes in the 1978 study were determined by the study contractor for the Provo River by using streamflow records at various locations along the river to generate a 64-year record (1912 through 1975) of annual peak snowmelt inflows at Deer Creek Dam and Reservoir, excluding imported water. These data were used for a log-Pearson Type III analysis (Reference 4) to determine the 10-, 50-, 100-, and 500-year inflow floods. These floods were then routed through the reservoir by a Modified Puls computer program (Reference 5) to determine reservoir outflow peaks. The reservoir was assumed to be full and the transmountain diversions cut off at the beginning of the routing sequence. Routing below the dam included the addition of snowmelt flooding from the 107 square miles below the reservoir and reduction by capacity of the Murdock Diversion and Timpanogos Canals at the mouth of the Provo Canyon to arrive at the flooding that would enter at the corporate limits. Recent gage records do not significantly alter the frequency curve.

Provo River flood magnitudes from the 1978 Provo Flood Insurance Study report were used in this study.

A gaging station near Lehi, Utah, located approximately 17 miles from Provo, was the source of data for defining lake level-frequency relationships from Utah Lake. The gage has been operated since 1884. Values of the 10-, 50-, 100-, and 500-year lake levels were obtained from a log-Pearson Type III (Reference 4) distribution of annual peak lake level data. It was found that a windset application would have a significant effect on lake water elevations. A wind fetch of 1.1 feet, assuming a northwest wind of

40 miles per hour, is added to the lake levels of desired frequency to determine the final flood elevations for Utah Lake.

The effects of record flood elevations on Utah Lake during the last few years are offset by the recent completion of a large headworks and dredging project at the Jordan River outlet, which greatly increases outflow from Utah Lake. Therefore, the Utah Lake flood elevations from the 1978 Provo Flood Insurance Study report were also used in this study.

Rock Canyon is the only frontal canyon for which any streamflow data is available. The USFS installed a streamgage just below the forks in Rock Canyon in 1975. The gage was operated until it was washed out during the spring snowmelt flood of 1983, giving a total of 8 years of record. During that time, peak annual discharges resulted from snowmelt, while no significant rainfall floods were recorded during the same period. A snowmelt flood frequency curve was determined for this record using a log-Pearson Type III distribution. It was weighted with flood frequency estimates from the most recent USGS regional method for estimating flood frequencies (Reference 6). This curve was then combined with a rainfall flood frequency curve, developed from the SCS Curve Number and Dimensionless Unit Hydrograph method, to form a combined flood frequency curve from which the 10-, 50-, 100-, and 500-year floodflows were determined.

The SCS Curve Number and Dimensionless Hydrograph method requires the estimation of various parameters. To reduce errors in the estimation of these parameters as much as possible, the method was calibrated with estimates derived from gage records of two nearby similar watersheds, Fort Creek and Dry Creek.

The flows for Little Rock Canyon, Slate Canyon, Slide Canyon, and Buckley Draw were developed in much the same way, but without a streamflow record. The USGS regional method (Reference 6) was used in conjunction with the SCS Curve Number and Dimensionless Unit Hydrograph method.

Flows from Rock and Slate Canyons were routed through their respective debris basins using the Modified Puls method. This significantly reduced the floodflows.

Peak discharge-drainage area relationships for the Provo River, Rock Canyon Creek, Slate Canyon Creek, Slide Canyon, Buckley Draw, and Little Rock Canyon are shown in Table 1.



TABLE 1. SUMMARY OF DISCHARGES

| Flooding Source and Location | Drainage Area (square miles) | Peak Discharges (cfs) 10-Year | 50-Year | 100-Year | 500-Year |
|---|---|---|---|---|---|
| Provo River | | | | | |
| 1 mile below mouth of Provo Canyon | 680.00 | 1,800 | 2,600 | 3,200 | 3,800 |
| Rock Canyon Creek | | | | | |
| At mouth of Rock Canyon | 9.92 | 115 | 280 | 450 | 890 |
| Below debris basin | 9.92 | 105 | 180 | 220 | 380 |
| Slate Canyon Creek | | | | | |
| At mouth of Slate Canyon | 6.04 | 74 | 172 | 274 | 550 |
| Below debris basin | 6.04 | 64 | 113 | 150 | 475 |
| Slide Canyon | | | | | |
| At canyon mouth | 1.18 | 21 | 37 | 53 | 110 |
| Buckley Draw | | | | | |
| At mouth | 0.84 | 16 | 28 | 40 | 90 |
| Little Rock Canyon | | | | | |
| At mouth | 0.70 | 16 | 27 | 32 | 50 |

Analyses were carried out to establish the peak elevation-frequency relationships for each flooding source studied by detailed methods.

Elevations for floods of the selected recurrence intervals on Utah Lake are shown in Table 2.

TABLE 2. SUMMARY OF ELEVATIONS
(National Geodetic Vertical Datum of 1929)

| Flooding Source and Location | 10-yr Flood | 50-yr Flood | 100-yr Flood | 500-yr Flood |
|---|---|---|---|---|
| Utah Lake at Provo | 4492.5 | 4494.0 | 4494.5 | 4495.3 |

## 3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

Cross sections for the backwater analyses of the Provo River were obtained by field surveys and extensions of these cross sections were obtained from aerial photographs (Reference 7).

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream sections for which the floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Boundary and Floodway Map (Exhibit 2).

Roughness coefficients (Manning's "n") for water-surface profile computations were determined by engineering experience and from field inspection of stream channels and overbank areas. Roughness values of 0.045 were used for the river channel and from 0.07 to 0.10 for overbank areas.

Water-surface profiles for the Provo River were developed using the HEC-2 step-backwater computer model (Reference 8). Profiles were determined for the 10-, 50-, 100-, and 500-year floods. Starting water-surface elevations were taken as the 10-, 50-, 100-, and 500-year water-surface elevations of Utah Lake.

Flood profiles for the Provo River and Slate Canyon are routed through detention basins using a Modified Puls method of flood routing (Reference 3). Flood boundaries below the detention basin and for Little Rock Canyon were determined using shallow flooding procedures.

Flood boundaries from Slide Canyon and Buckley Draw were determined using alluvial fan methods. Due to the minimal amount of flood hazard determined for the areas, flood boundaries and flood hazards were not delineated.

The Utah Lake dike and Provo River levees protect large areas of farmland interspersed with housing. Recent improvements to these levees by the City of Provo and the COE are in accordance with FEMA specifications, and the areas protected by these levees below the 100-year level of Utah Lake have been designated as Zone X.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Insurance Rate Map (Exhibit 2).

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

All elevations are referenced to the National Geodetic Vertical Datum (NGVD) of 1929. Elevation reference marks used in this study are shown on the maps; the descriptions of the marks are presented in Elevation Reference Marks (Exhibit 3).



# 4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages state and local governments to adopt sound floodplain management programs. Therefore, each Flood Insurance Study provides 100-year flood elevations and delineations of the 100- and 500-year floodplain boundaries and 100-year floodway to assist communities in developing floodplain management measures.

## 4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1 percent annual chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2 percent annual chance (500-year) flood is employed to indicate additional areas of flood risk in the community. For each stream studied in detail, the 100- and 500-year floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:1,200, with a contour interval of 2 feet (Reference 7).

The 100- and 500-year floodplain boundaries are shown on the Flood Insurance Rate Map (Exhibit 2). On this map, the 100-year floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, and AO); and the 500-year floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 100- and 500-year floodplain boundaries are close together, only the 100-year floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 100-year floodplain boundary is shown on the Flood Insurance Rate Map (Exhibit 2.)

## 4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 100-year floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated at selected cross sections (Table 3). In cases where the floodway and 100-year floodplain boundaries are either close together or collinear, only the floodway boundary has been shown.

The area between the floodway and 100-year floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 2.

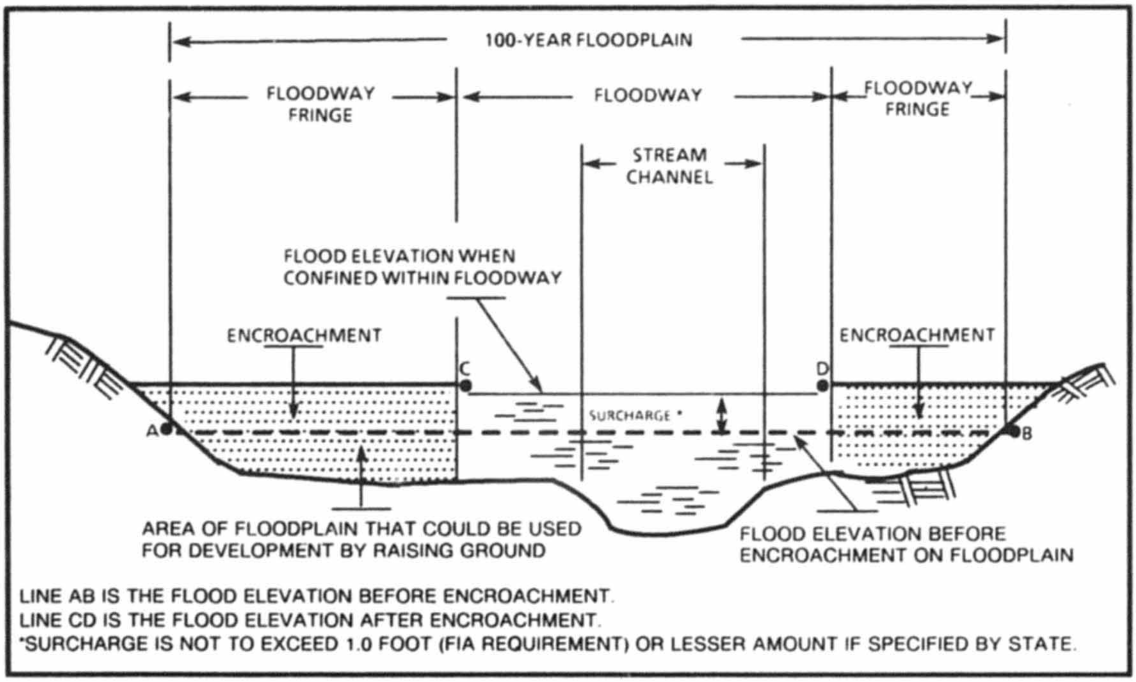



Figure 2. Floodway Schematic

Table 3. Floodway Data

| FLOODING SOURCE | | FLOODWAY | | | BASE FLOOD ELEVATION | | | |
|---|---|---|---|---|---|---|---|---|
| Cross Section | Distance[1] | Width (Feet) | Section Area (Square Feet) | Mean Velocity (Feet per Second) | Regulatory (Feet) | Without Floodway (Feet) | With Floodway (Feet) | Increase (Feet) |
| Provo River | | | | | | | | |
| A | 1.840 | 112 | 980 | 3.3 | 4,497.4 | 4,497.4 | 4,498.1 | 0.7 |
| B | 2.834 | 92 | 538 | 6.0 | 4,510.8 | 4,510.8 | 4,510.8 | 0.0 |
| C | 3.280 | 104 | 502 | 6.4 | 4,519.3 | 4,519.3 | 4,519.9 | 0.6 |
| D | 3.318 | 87 | 420 | 7.6 | 4,520.9 | 4,520.9 | 4,520.9 | 0.0 |
| E | 3.526 | 48 | 424 | 7.6 | 4,527.3 | 4,527.3 | 4,527.6 | 0.3 |
| F | 3.601 | 101 | 584 | 5.5 | 4,529.1 | 4,529.1 | 4,529.3 | 0.2 |
| G | 3.663 | 99 | 496 | 6.4 | 4,530.2 | 4,530.2 | 4,530.3 | 0.1 |
| H | 3.701 | 90 | 482 | 6.6 | 4,531.1 | 4,531.1 | 4,531.2 | 0.1 |
| I | 3.751 | 111 | 526 | 6.1 | 4,532.0 | 4,532.0 | 4,533.0 | 1.0 |
| J | 4.135 | 60 | 372 | 8.6 | 4,545.4 | 4,545.4 | 4,546.2 | 0.8 |
| K | 4.487 | 61 | 396 | 8.1 | 4,557.7 | 4,557.7 | 4,558.4 | 0.7 |
| L | 4.539 | 62 | 365 | 8.8 | 4,561.0 | 4,561.0 | 4,561.0 | 0.0 |
| M | 4.630 | 73 | 416 | 7.7 | 4,564.1 | 4,564.1 | 4,564.4 | 0.3 |
| N | 4.649 | 71 | 468 | 6.8 | 4,564.8 | 4,564.8 | 4,565.0 | 0.2 |
| O | 5.034 | 90 | 569 | 5.6 | 4,577.4 | 4,577.4 | 4,577.4 | 0.0 |
| P | 5.054 | 85 | 300 | 10.7 | 4,580.2 | 4,580.2 | 4,580.2 | 0.0 |
| Q | 5.136 | 87 | 492 | 6.5 | 4,587.0 | 4,587.0 | 4,587.0 | 0.0 |
| R | 5.184 | 70 | 453 | 7.1 | 4,587.6 | 4,587.6 | 4,587.7 | 0.1 |
| S | 5.524 | 68 | 386 | 8.3 | 4,599.9 | 4,599.9 | 4,599.9 | 0.0 |
| T | 5.749 | 60 | 360 | 8.9 | 4,607.9 | 4,607.9 | 4,608.1 | 0.2 |
| U | 5.805 | 67 | 312 | 10.3 | 4,609.6 | 4,609.6 | 4,609.6 | 0.0 |
| V | 6.012 | 71 | 384 | 8.3 | 4,620.2 | 4,620.2 | 4,620.3 | 0.1 |
| W | 6.049 | 65 | 305 | 10.5 | 4,621.9 | 4,621.9 | 4,621.9 | 0.0 |
| X | 6.071 | 60 | 266 | 12.0 | 4,627.0 | 4,627.0 | 4,627.0 | 0.0 |
| Y | 6.393 | 150 | 537 | 6.0 | 4,641.9 | 4,641.9 | 4,642.8 | 0.9 |
| Z | 6.441 | 140 | 476 | 6.7 | 4,643.9 | 4,643.9 | 4,644.3 | 0.4 |

[1] Miles Above Mouth

Table 3. Floodway Data

| FLOODING SOURCE | | FLOODWAY | | | BASE FLOOD ELEVATION | | | |
|---|---|---|---|---|---|---|---|---|
| Cross Section | Distance[1] | Width (Feet) | Section Area (Square Feet) | Mean Velocity (Feet per Second) | Regulatory (Feet) | Without Floodway (Feet) | With Floodway (Feet) | Increase (Feet) |
| Provo River (Cont'd) | | | | | | | | |
| AA | 6.479 | 70 | 381 | 8.4 | 4,645.4 | 4,645.4 | 4,645.6 | 0.2 |
| AB | 6.702 | 70 | 368 | 8.7 | 4,655.2 | 4,655.2 | 4,655.3 | 0.1 |
| AC | 7.434 | 69 | 357 | 9.0 | 4,689.2 | 4,689.2 | 4,689.6 | 0.4 |
| AD | 7.463 | 58 | 276 | 11.6 | 4,690.6 | 4,690.6 | 4,690.7 | 0.1 |
| AE | 8.227 | 120 | 500 | 6.4 | 4,729.0 | 4,729.0 | 4,729.0 | 0.0 |
| AF | 8.619 | 72 | 340 | 9.4 | 4,744.4 | 4,744.4 | 4,744.4 | 0.0 |
| AG | 8.657 | 69 | 279 | 11.5 | 4,747.8 | 4,747.8 | 4,747.8 | 0.0 |
| AH | 9.357 | 57 | 380 | 8.4 | 4,785.3 | 4,785.3 | 4,785.3 | 0.0 |
| AI | 9.380 | 54 | 356 | 9.0 | 4,785.8 | 4,785.8 | 4,785.8 | 0.0 |

[1] Miles Above Mouth

## 5.0 INSURANCE APPLICATION

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. These zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by detailed methods. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No base flood elevations or depths are shown within this zone.

## 6.0 FLOOD INSURANCE RATE MAP

The Flood Insurance Rate Map is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 100-year floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.



For floodplain management applications, the map shows by tints, screens, and symbols the 100- and 500-year floodplains, floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

## 7.0 OTHER STUDIES

The peak discharge estimates used in the published Flood Insurance Study for the Provo River were adopted for use in this study. These values are consistent with previous studies by the COE.

The published Flood Insurance Study used a log-Pearson Type III analysis on the Utah Lake near Lehi gage record to estimate the peak lake level frequency curve. High lake levels from 1983 to 1985 would result in a higher 100-year lake level. Substantial improvements in the outlet to the lake provide for larger releases and a controlled maximum lake level; therefore, the predetermined levels were used in this report.

Flood-frequency estimates for Rock Canyon have been developed by the COE (Reference 9), two Brigham Young University (BYU) graduate students (References 10 and 11), and by the former Flood Insurance Study (Reference 12). The 100- and 500-year peak discharge estimates used in the published Flood Insurance Study were derived from the COE results, while the 10- and 50-year estimates were derived using the rational formula. Documentation of the exact methods and parameters used in deriving the COE estimates could not be located.

The COE and the published Flood Insurance Study cloudburst peak discharge estimates were based on methods which were not calibrated to a watershed the size of Rock Canyon. The rational formula is not appropriate for use on watersheds greater than 200 acres (0.31 square miles).

The estimates from the two BYU graduate studies were based on regional methods which utilized statistical analyses of actual streamflow records and are similar to estimates in this Flood Insurance Study.

Previous flood-frequency estimates for Slate Canyon have been developed by the COE (Reference 13), by the former Flood Insurance Study for the City of Provo (Reference 12), and by John M. Tettemer and Associates, Ltd. (Reference 14). All these analyses were based on the assumption of cloudburst type floods and used uncalibrated synthetic methods. The only previous study estimating peak discharges for Slide Canyon was conducted by Community Consultants, Inc. (Reference 15). This study computes the 100-year flood using six different methods which produced estimates ranging from 29.8 to 60.8 cfs. The 100-year peak discharge estimate presented herein is within this range. The only previous study which estimates peak discharges for Little Rock Canyon is the former Flood Insurance Study which uses the McMath formula, a variation of the rational formula (Reference 12). These formulas are not appropriate for a watershed the size of Little Rock Canyon, but are to be used on drainages less than 200 acres. No previous studies have been conducted for Buckley Draw.

This study is authoritative for the purposes of the National Flood Insurance Program; data presented herein either supersede or are compatible with all previous determinations.

## 8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting the Natural and Technological Hazards Division, FEMA, Denver Federal Center, Building 710, Box 25267, Denver, Colorado 80225-0267.

## 9.0 BIBLIOGRAPHY AND REFERENCES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## EXHIBIT 3 - ELEVATION REFERENCE MARKS
## CITY OF PROVO, UTAH COUNTY, UTAH

| Reference Mark | Elevation (feet NGVD) | Description of Location |
|---|---|---|
| RM 1 | 4824.74 | Utah Department of Transportation bench mark, orange arrow painted on top of support block on southeast side of Olmstead Bridge at mouth of Provo Canyon. |
| RM 2 | 4779.62 | Utah County Surveyors section tie 3" brass cap on 2" pipe set 12" above the ground 100 feet west of pavement on Edgewood Drive .15 miles south of Carterville Road Intersection. |
| RM 3 | 5807.97 | Utah County Surveyor's section tie, 3" brass cap on 2" iron pipe set in concrete 3" above ground 13.79 feet SW of corner fence post on SW corner of 4800 N. And university Avenue intersection. |
| RM 4 | 4695.03 | Utah County Surveyors section tie 3" brass cap set in concrete 12" below ground level. 3.71 feet north of telephone pole on northeast corner of Lot on northwest corner of 3700 North 100 East. |
| RM 5 | 4693.13 | Benchmark at an irrigation canal gate, in top of west wall, 3.7 miles north along Abandoned Railroad grade from courthouse at Prove. "Disk stamped "1922H144693." |
| RM 6 | 4650.57 | Rollins, Brown, Gunnell, Inc. temporary bench mark, "X" etched in north concrete wall of the Riverside Golf Course bridge 4 feet from the 5th pole from the east side of bridge. |
| RM 7 | 4629.88 | Provo City Bench mark #26, brass monument in the sidewalk 16.40 feet from the eastern edge of the north sidewalk of the 2230 N. St. bridge. |
| RM 8 | 4618.90 | Rollins, Brown, and Gunnell, Inc. temporary bench mark; the top of the north fence post cap on the chain link fence northeast of University Parkway bridges. |

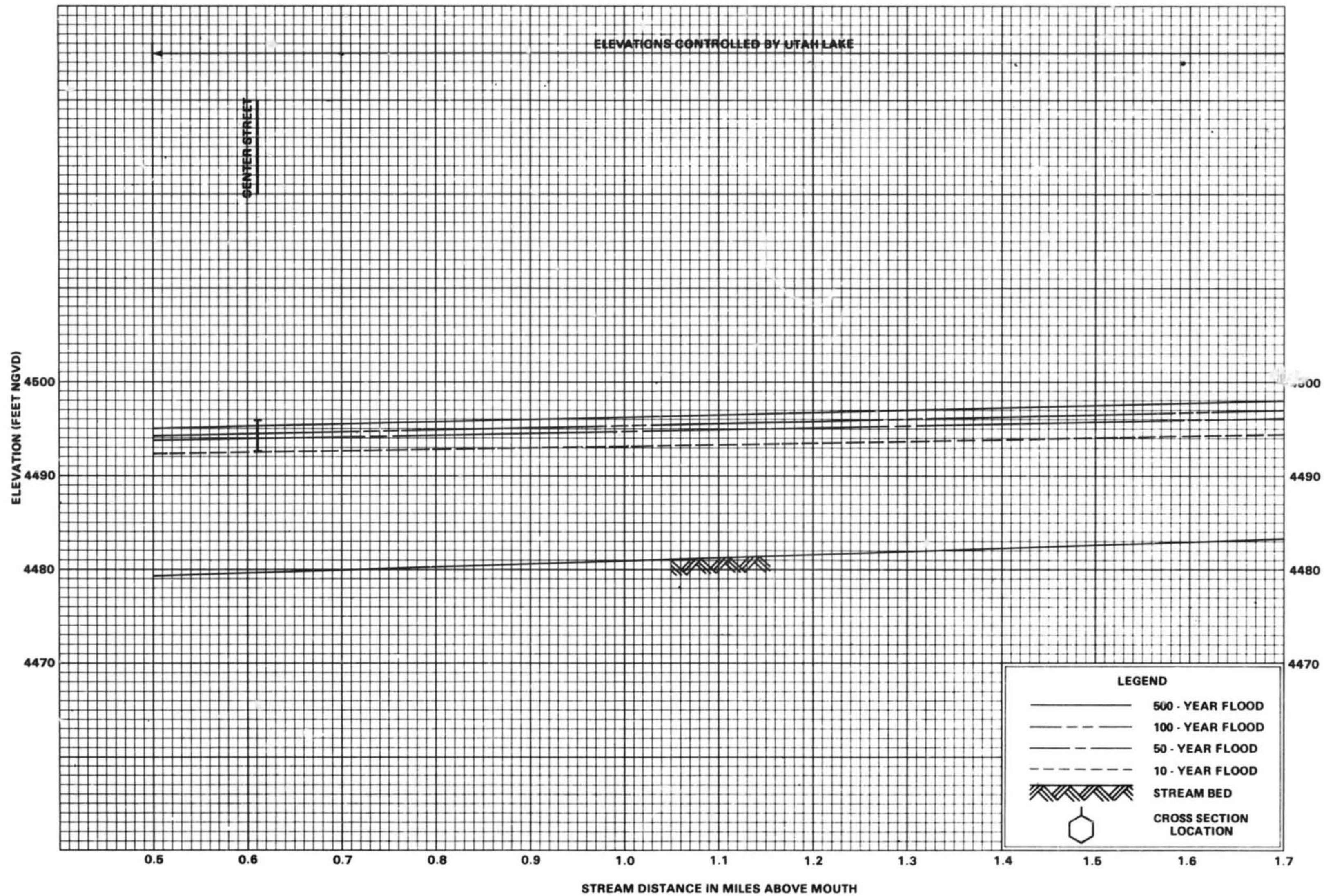


## EXHIBIT 3 - ELEVATION REFERENCE MARKS (cont.)
## CITY OF PROVO, UTAH COUNTY, UTAH

| Reference Mark | Elevation (feet NGVD) | Description of Location |
|---|---|---|
| RM 9 | 4588.85 | Provo City Bench Mark #32, monument 72.00 feet northwest from the corner of the Constitution Mint Building on a chain link fence line along the south side of Columbia Lane and east of Riverside Avenue. |
| RM 10 | 4563.03 | Provo City Bench Mark #33, monument approximately 8.40 feet south of the power pole located just north of the sidewalk on the northeast corner of the intersection of 800 N and 800 W, Provo. |
| RM 11 | 4549.54 | Disk set on top of 3 1/2 inch iron pipe stamped 1922 H 15, 35 feet south-west of the southwest corners of the intersection of Center and 100 East Streets. |
| RM 12 | 4530.05 | Disk set in concrete post, stamped 4530.083 S17 1927, located between Denver and Rio Grande Western Railroad tracks, 63 feet northwest of Provo viaduct located along Interstate 15. |
| RM 13 | 4528.00 | Rollins, Brown, and Gunnell, Inc. temporary bench mark, "X" in top of southwest corner of concrete wing wall of I-15 freeway overpass. |
| RM 14 | 4524.43 | Rollins, Brown, and Gunnell, Inc. top of south west bolt of 4 bolts anchoring guard rail on southeast wing wall of Geneva Road Bridge over Provo River. |
| RM 15 | 4496.26 | Disk set in concrete post stamped JR 28 at the southeast fence corner of the intersection of west center and 3110 West Streets |
| RM 16 | 4492.33 | Provo City Bench Mark #135, monument approximately 50 feet west of the fire hydrant in front of the red brick house at 3420 W. Center St., Provo. |

EXHIBIT 3 - ELEVATION REFERENCE MARKS (cont.)
CITY OF PROVO, UTAH COUNTY, UTAH

| Reference Mark | Elevation (feet NGVD) | Description of Location |
|---|---|---|
| RM 17 | 4495.91 | Provo City BM #134 brass cap on southeast wing wall of the Center Street Bridge over Provo River at Utah Lake State Park. |



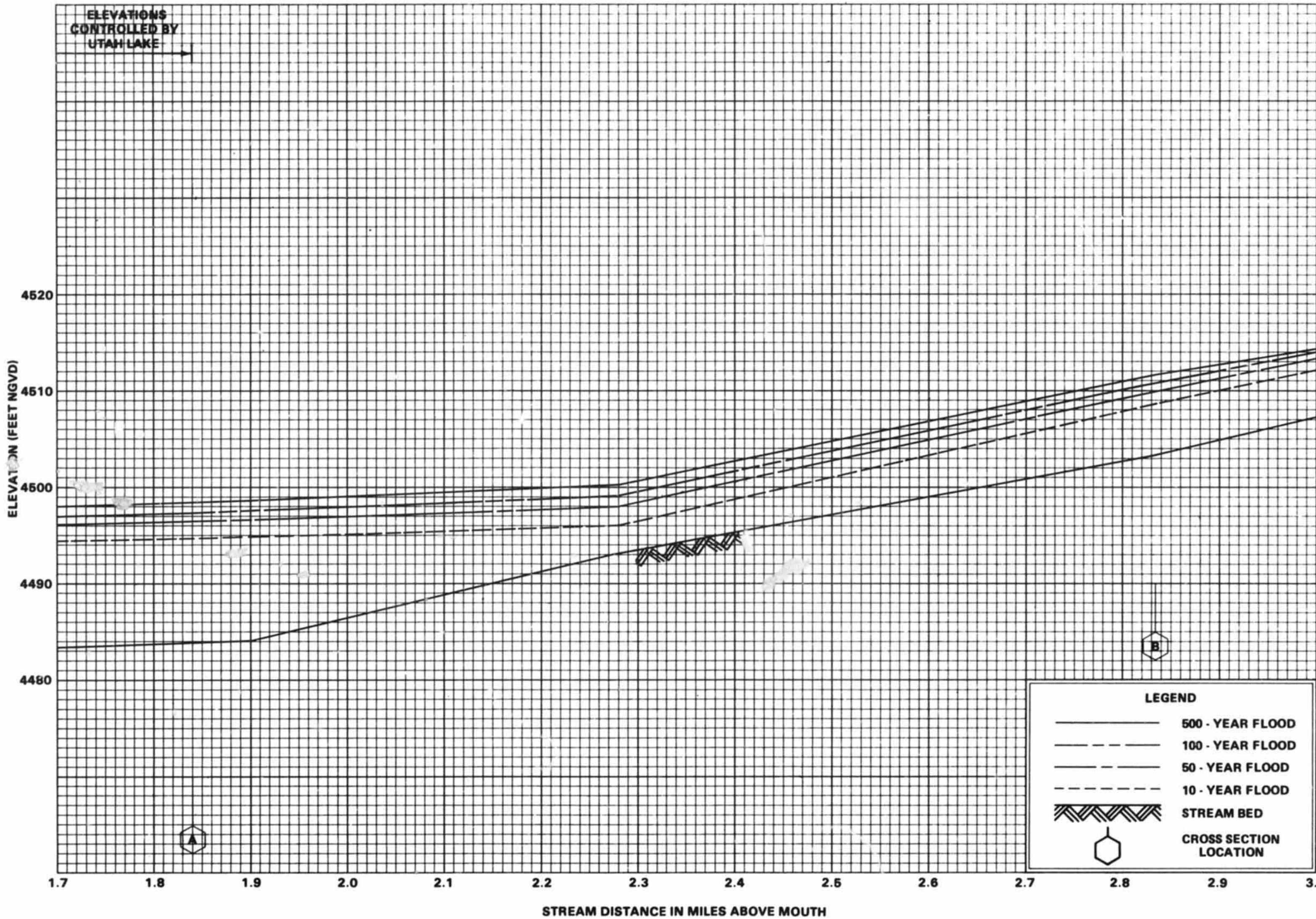

FLOOD PROFILES

PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

01P



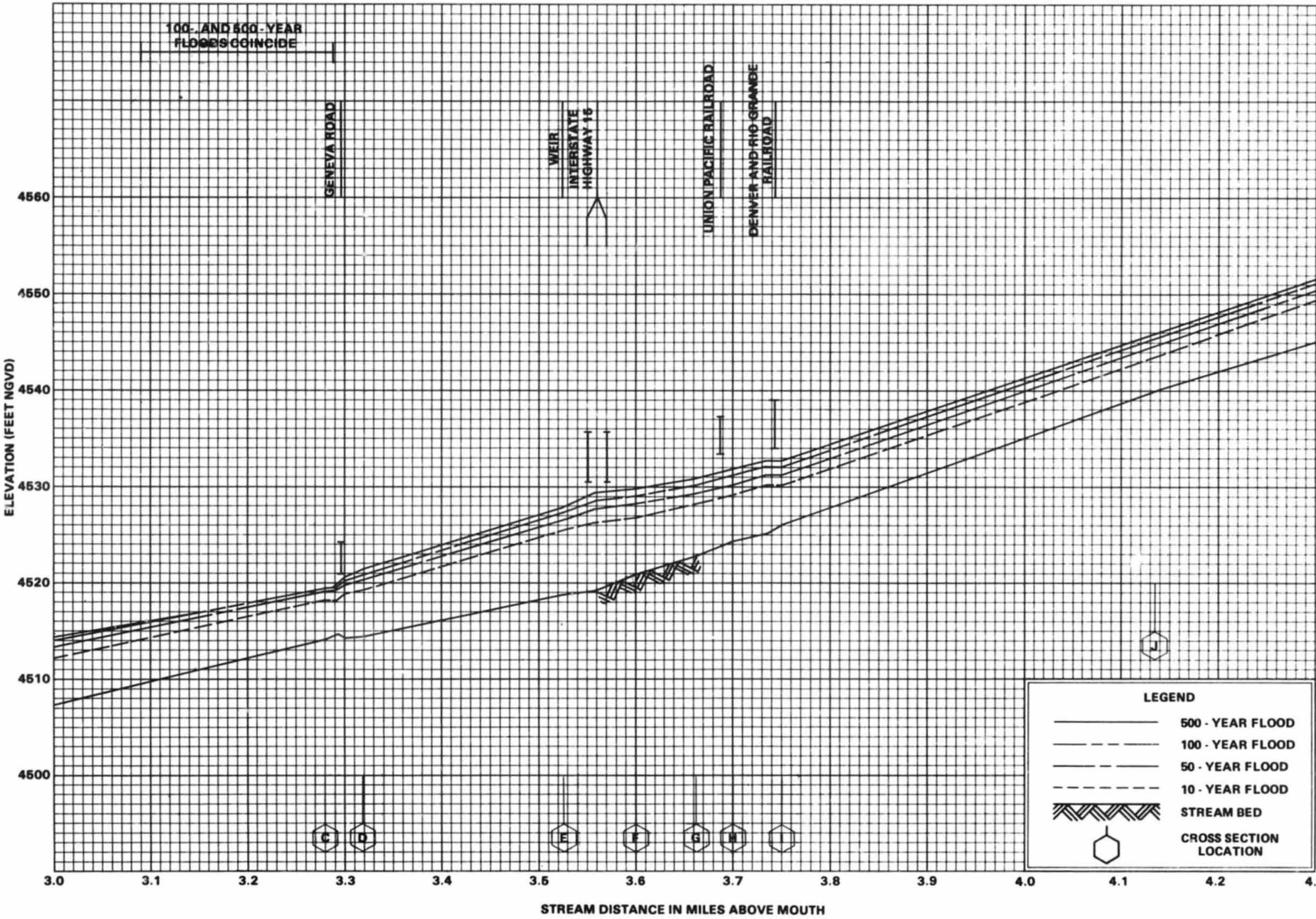

FLOOD PROFILES

PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

02P



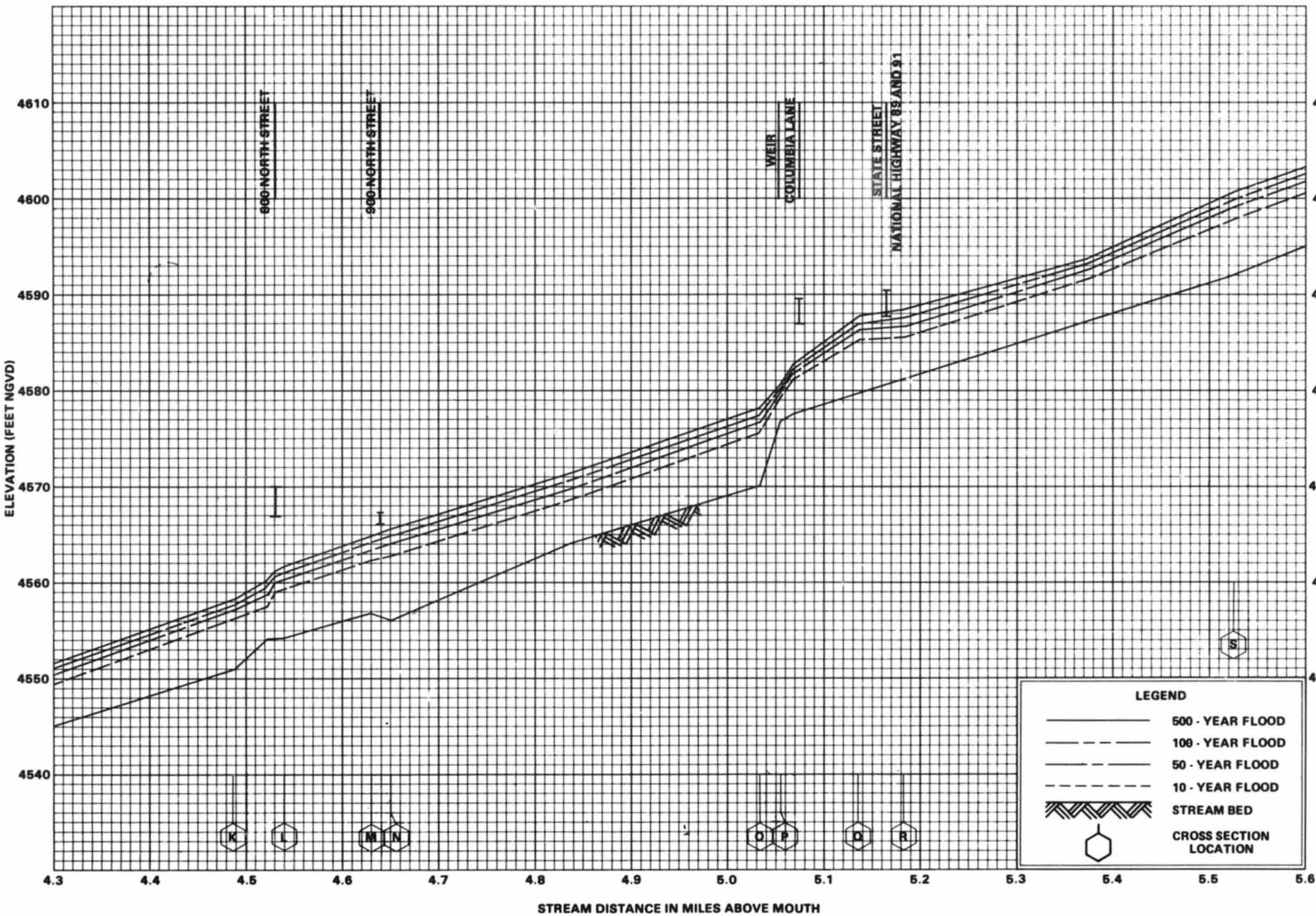

FLOOD PROFILES

PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

03P



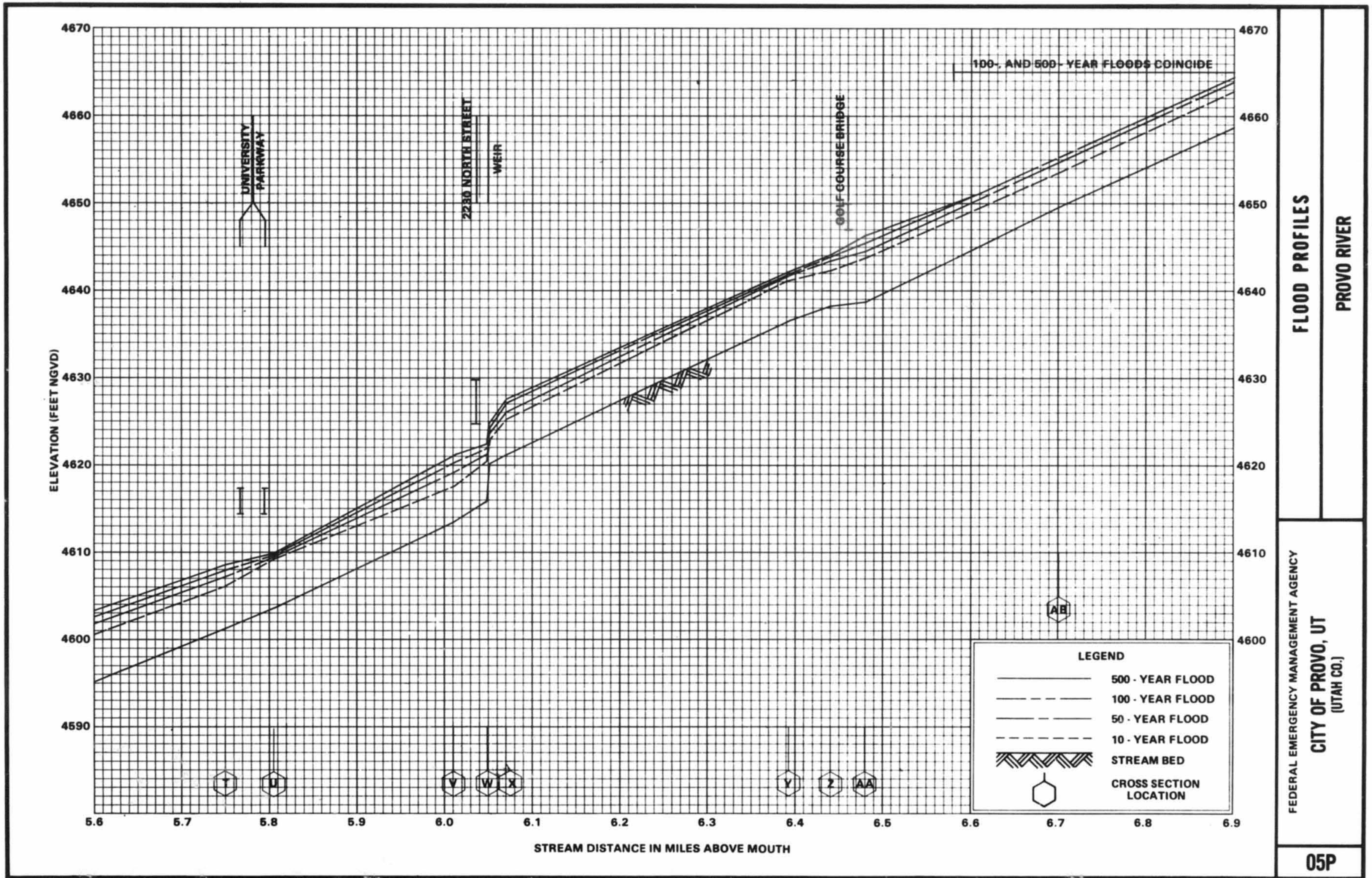

FLOOD PROFILES

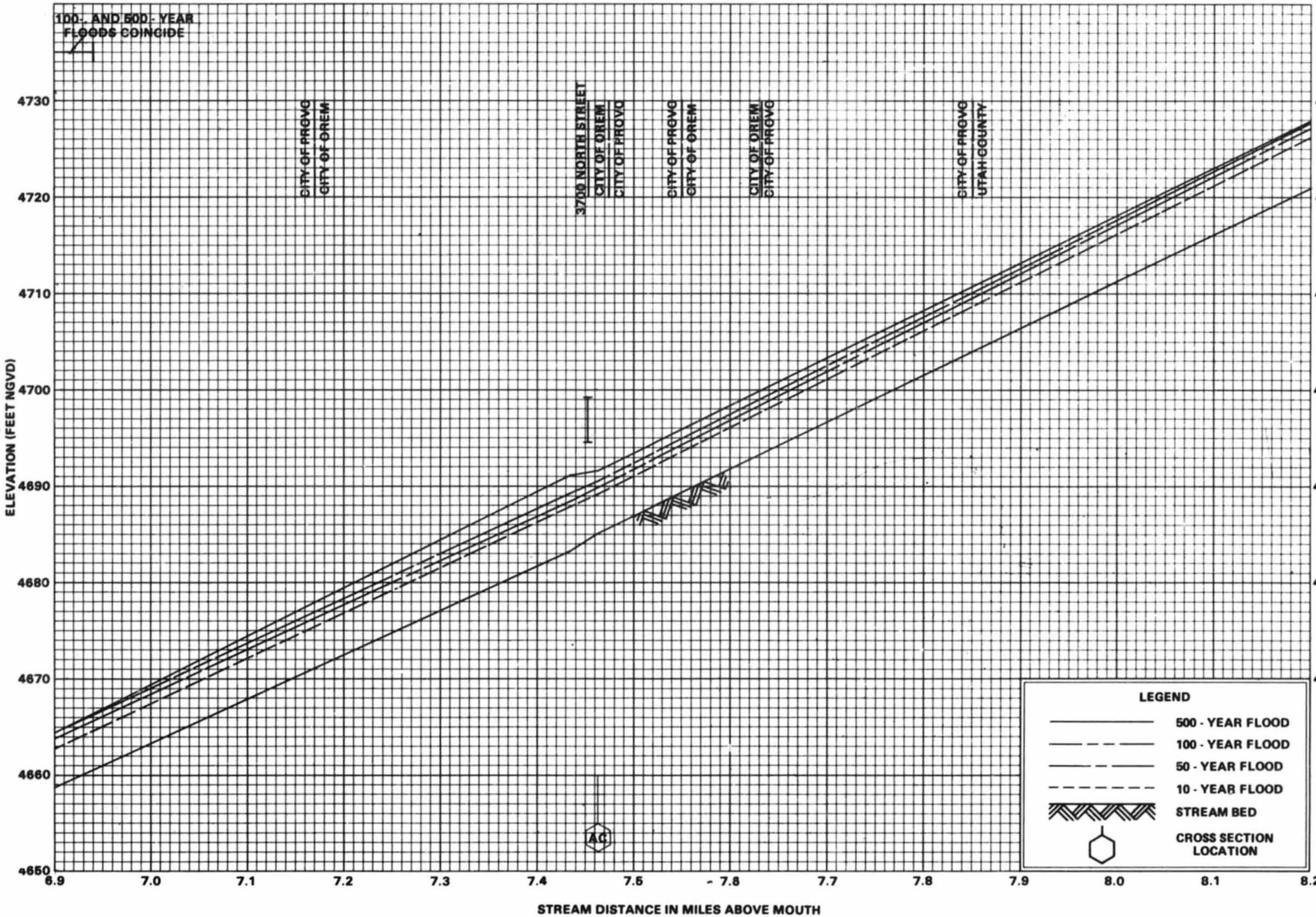
PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

04P


FLOOD PROFILES
PROVO RIVER
FEDERAL EMERGENCY MANAGEMENT AGENCY
CITY OF PROVO, UT
(UTAH CO.)
05P
ELEVATION (FEET NGVD)
STREAM DISTANCE IN MILES ABOVE MOUTH
4590
4600
4610
4620
4630
4640
4650
4660
4670
5.6
5.7
5.8
5.9
6.0
6.1
6.2
6.3
6.4
6.5
6.6
6.7
6.8
6.9
100-, AND 500 - YEAR FLOODS COINCIDE
UNIVERSITY PARKWAY
2230 NORTH STREET
WEIR
GOLF COURSE BRIDGE
T
U
V
W
X
Y
Z
AA
AB
LEGEND
500 - YEAR FLOOD
100 - YEAR FLOOD
50 - YEAR FLOOD
10 - YEAR FLOOD
STREAM BED
CROSS SECTION LOCATION



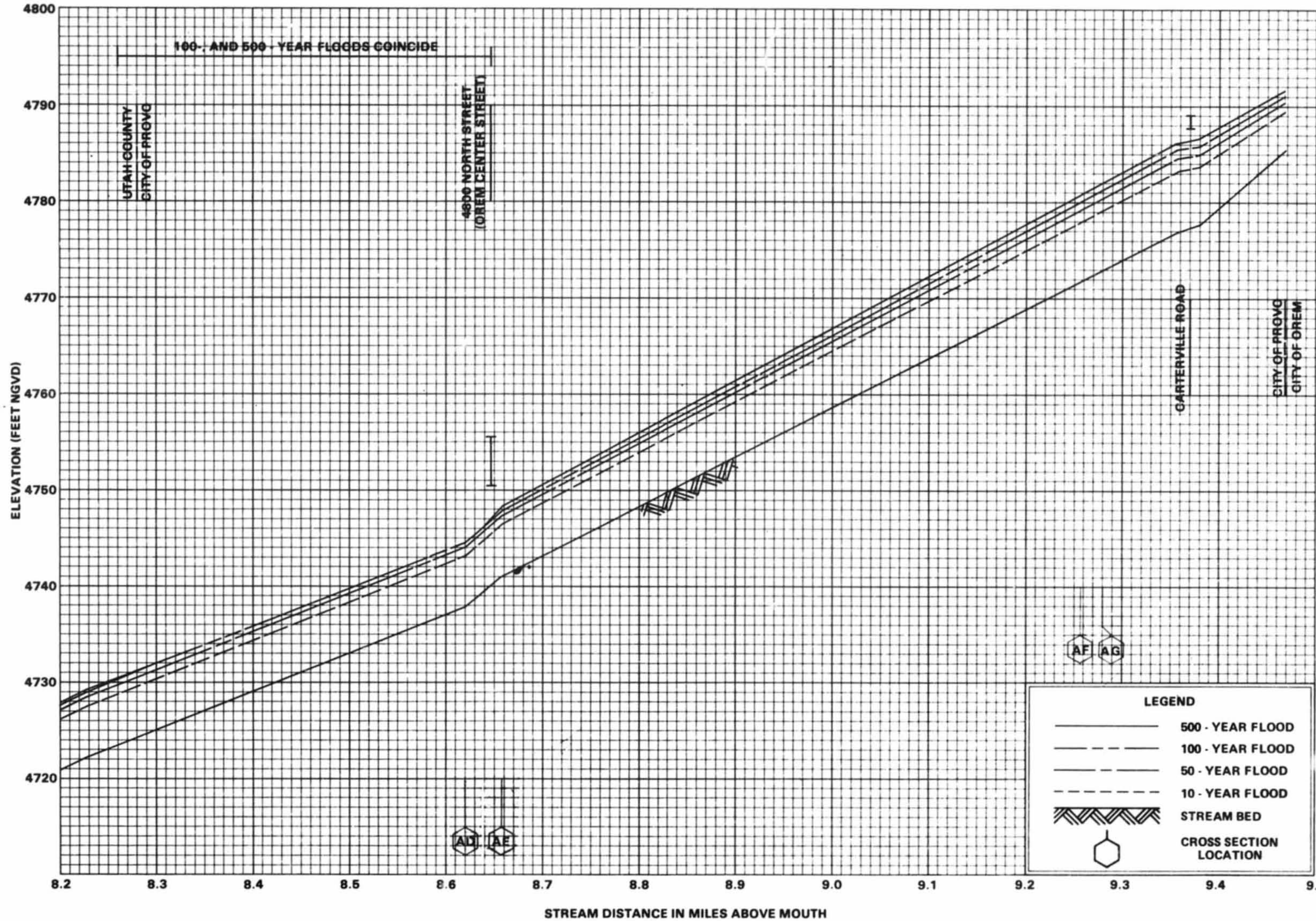

FLOOD PROFILES

PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

06P




FLOOD PROFILES

PROVO RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF PROVO, UT
(UTAH CO.)

07P