UTAH GEOLOGICAL AND MINERAL SURVEY

REPORT OF INVESTIGATION

NO. 197

DAM FAILURE INUNDATION STUDY FOR DEER CREEK DAM, UTAH COUNTY

by
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FORWARD

A principal objective of the Utah Geological and Mineral Survey is the identification of areas of Utah that are exposed to geologic hazards. Geologic events such as earthquakes, landslides, and debris flows can cause dams to fail and produce flooding downstream. Inundation mapping is thus an essential ingredient in any comprehensive hazard mapping effort. Deer Creek Dam was chosen for this inundation study, the first by the Utah Geological and Mineral Survey (UGMS), because of special interest expressed by the State Division of Comprehensive Emergency Management and the Utah County Office of Emergency Preparedness. The reservoir is one of the more significant water impoundments along the Wasatch Front and would impact a considerable population if it were to fail. Because topographic maps of Provo River Canyon, downstream from the dam, are exceptional in scale and contour interval, a more accurate inundation map can be produced here than would be possible in most areas.

This report is intended to present the results of the inundation study and to document the procedures adopted by the UGMS in the preparation of inundation area maps. A byproduct of this study is the travel time of the released reservoir water as it moves downstream. With this information, emergency preparedness personnel may estimate time available for escape along evacuation routes. Shelter zones can be established when the potential inundation zone is determined. Potential inundation is but one hazard that must be considered in the siting of critical facilities. It is one hazard, however, that is commonly ignored by both public and private sectors.

I join Mr. Case in extending our gratitude to the U. S. Bureau of Reclamation for their kind assistance with this study.

Bruce N. Kaliser

State Hazard Geologist

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ACKNOWLEDGMENTS

I would like to thank the Utah County Flood Control office and the Utah State Department of Transportation for the use of their large-scale maps of the study area. The Utah State Department of Comprehensive Emergency Management has provided necessary support and assistance. The Bureau of Reclamation, specifically Brent D. Taylor, has provided technical assistance which has made this report possible. Any errors, conceptual or arithmetic, are the author's.

INTRODUCTION

Deer Creek Dam is an earthfill dam on the Provo River in the Wasatch Range east of Utah Valley. The Provo River originates in the western part of Unita Mountains and flows in a northwesterly direction to Utah Lake. The natural flow of the Provo River is augmented by water diverted from the North Fork of the Duchesne River and the Weber River. The Deer Creek Dam is part of the Provo River Project, which delivers Provo River water to metropolitan areas of Utah and Salt Lake Counties. Deer Creek Reservoir, formed by the dam, has a capacity of 152,000 acre-feet. Downstream from the dam the Provo River flows through Orem and Provo. The dam provides flood protection for these communities, but if the dam should fail and release water from Deer Creek Reservoir into the Provo River, parts of these communities would be inundated. The purpose of the study reported here was to determine the area that would be inundated by an instantaneous failure of Deer Creek Dam with the reservoir filled to capacity--the worst-case scenario.

The study area extends from Deer Creek Dam to Utah Lake, 20.3 river miles (mileage along streambed, from dam) downstream along the Provo River (fig. 1). U.S. Highway 189 which connects Provo, Utah with Evanston, Wyoming (via

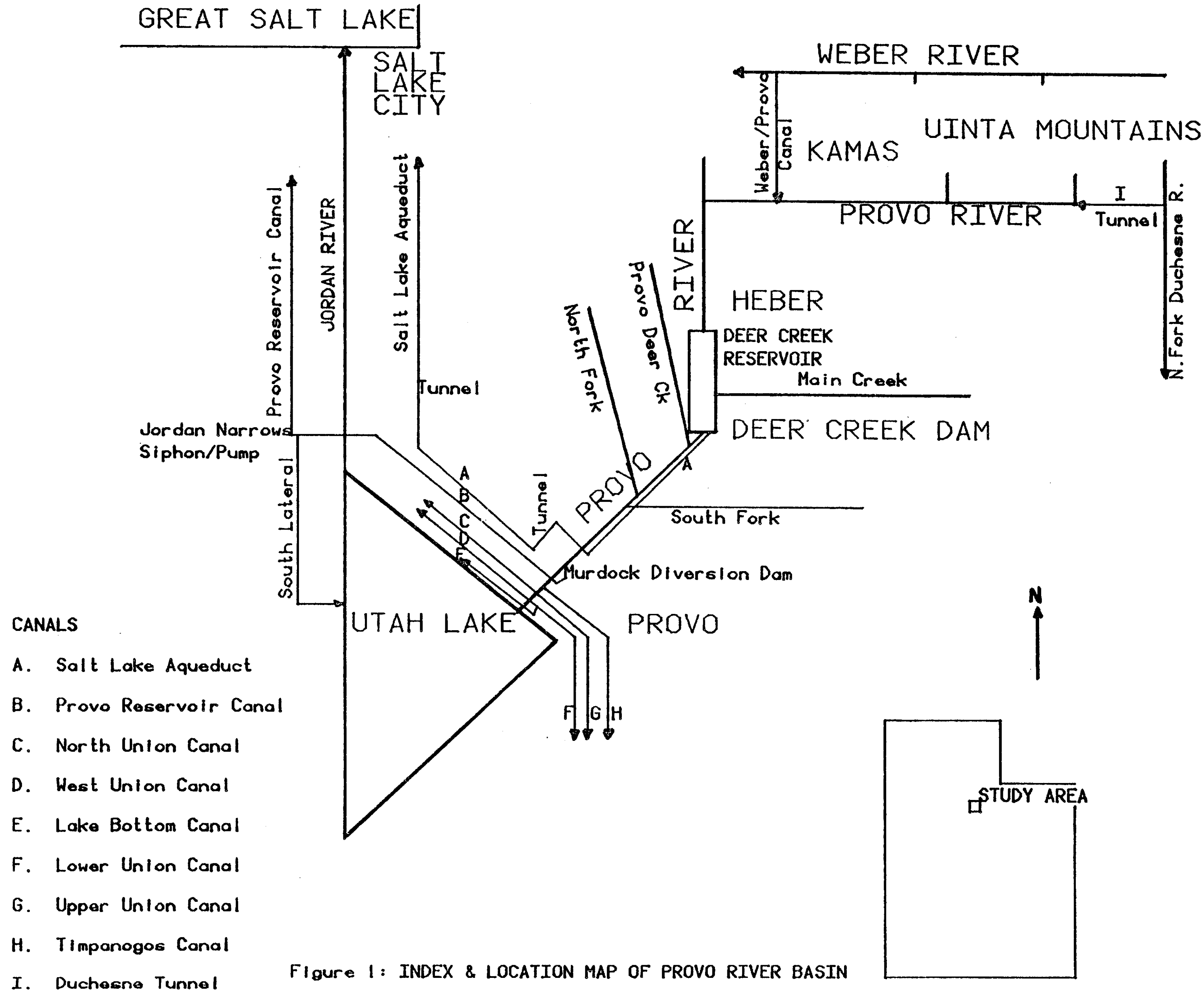

Figure 1: INDEX & LOCATION MAP OF PROVO RIVER BASIN

Interstate 80) runs parallel to the Provo River in the study area. Utah Highway 92, the "Alpine Loop" from American Fork which terminates at Wildwood and Highway 189 approximtely 4 miles below Deer Creek Dam, is the only other transportation route out of the Provo River Canyon. The tributaries that flow into the Provo River in the study area are as follows: A) Provo Deer Creek (river mile 0.74) has an approximate maximum discharge on the order of 100 sec.-ft. (Butler, 1966); B) North Fork, which enters the Provo River at Wildwood (river mile 3.95) has an approximate maximum discharge of about 225 sec.-ft. (Butler, 1966); and C) South Fork which enters the Provo River at Vivian Park (river mile 5.32) has an approximate maximum discharge of 125 sec.-ft. (Butler, 1966).

The headlands of the Provo River are in the Uinta Mountains approximately 40 miles east of Deer Creek Dam. Water is transferred from the North Fork of the Duchesne River to the Provo River through the Duchesne Tunnel (I on fig. 1) and from the Weber River along the Weber-Provo canal (fig. 1). The Duchesne Tunnel has a capacity of 600 sec.-ft. and the Weber-Provo canal can route 1000 sec.-ft. The drainage area of the Provo River above the mouth of Provo Canyon (river mile 11) to Deer Creek Dam (river mile 0.00) is 666 sq. mi. (Corps of Engineers, 1971). The Corps of Engineers (1971) has defined the peak discharge of the Intermediate Regional Flood (100-yr flood) to be 3000 sec.-ft. and the peak discharge of the Standard Project Flood ("The most severe combination of meteorological conditions reasonably characteristic of the geographical region, excluding extremely rare combinations") to be 5200 sec.-ft. at the mouth of Provo Canyon. Peak discharges of the Provo River (Corps of Engineers, 1971) are approximtely 2200 sec.-ft. at Deer Creek Dam 3200 sec.-ft. at Vivian Park (river mile 5.32) and 2500 sec.-ft. at Provo, 1300 feet downstream from the bridge at Highway 114 (river mile 17.67).

Most of the population that would be affected by a flood on the Provo River live in Utah County, downstream from the county line at Wildwood (river mile 3.95). Canyon Meadows Sales Offices (river mile 1), Deer Creek Park Campground (river mile 0.75), and residential buildings along Provo Deer Creek are the only populated zones in Wasatch County, upstream from Wildwood, that would be affected by a flood due to Deer Creek Dam failure. A flood along the Provo River below Deer Creek Dam would affect people in the cities of Orem and Provo which have a 1980 census population of 52,399 and 73,907 respectively, and represent 58 percent of the population of Utah County. A flood of the magnitude suggested by this report is expected to indirectly affect at least 100,000 people due to disruption of lifelines. The residential areas downstream from the Utah County line to the canyon mouth include Wildwood (river mile 3.95), Vivian Park (river 5.32), Canyon Glen (river mile 8.2) and Springdell (river mile 8.6). Commercial facilities include River Bend Trailer Park and a general store (river mile 5.05), Bridal Veil Falls tram, etc. (river mile 7.15) and a cafe near Wicks (river mile 9.3). Industrial facilities in the Provo River Canyon include a gravel pit (river mile 10.5) and Utah Power and Light hydropower plant at Olmstead in the mouth of the canyon (river mile 10.8). A hydropower plant at the base of Deer Creek Dam can release 1500 sec.-ft. into the Provo River, enough to cause slight flooding damage in Provo River Canyon. The water transmission facilities (fig. 1) within Provo River Canyon are the Salt Lake City (Deer Creek) Aqueduct (A on fig. 1) which has a capacity of 150 sec.-ft. and routes water from Deer Creek Dam to Salt Lake City, the Provo Reservoir Canal/Murdock Canal (B on fig. 1) which routes water from Murdock/Olmstead diversion dam to the west side of Jordan River Valley, and the Union Canal (not shown on fig. 1) which provides Provo River water to the Olmstead hydropower plant. The

Murdock/Olmstead dam is a gravity dam which diverts approximately 550 sec.-ft. into the Jordan River Valley. Below the canyon mouth 6 canals distribute water along the Wasatch Front (fig. 1), water is routed to the north by the North Union (C on fig. 1), West Union (D on fig. 1), and Lake Bottom (E on fig. 1) canals, and to the south water is routed by the Lower Union (F on fig. 1), Upper Union (G on fig. 1), and Timpanogos (H on fig. 1) canals. The Provo River, after leaving the canyon, passes through the communities of Orem, Caryhurst, Edgemont, Pleasant View, and Provo on its way to Utah Lake State Park. The elevation range of the study area is from 5425 feet at Deer Creek Dam crest to about 4490 feet at Utah Lake.

The geology of Provo River Canyon in the study area is examined to estimate the resistance to hydraulic erosion of the streambed and valley walls. Erosion as defined for the purpose of this report consists of removal of sediment and bedrock by 1) abrasion by transported materials within flood waters such as sand, trees, boulders, etc.; 2) hydraulic plucking or dislodging of sediment and bedrock by flood water pressure; and 3) solution of geologic units by water. Three age groups are represented in the canyon:
A) Quaternary-age sediments, which are less than 1.8 million years old;
B) Pennsylvanian-age sedimentary rocks (320 to 280 million years old); and
C) Mississippian-age sedimentary rocks that were deposited before the Pennsylvanian rocks but after 345 million years ago. The geologic formations in the study area are Great Blue Limestone (Mississippian age), Manning Canyon Shale (late Mississippian or early Pennsylvanian age) and Oquirrh Formation of Pennsylvanian age which is basically sandstone with Bridal Veil Limestone Member.

The Quaternary sediments are unconsolidated or semiconsolidated and are classified by the agent that deposited them (fig. 2): Qal is alluvium/valley

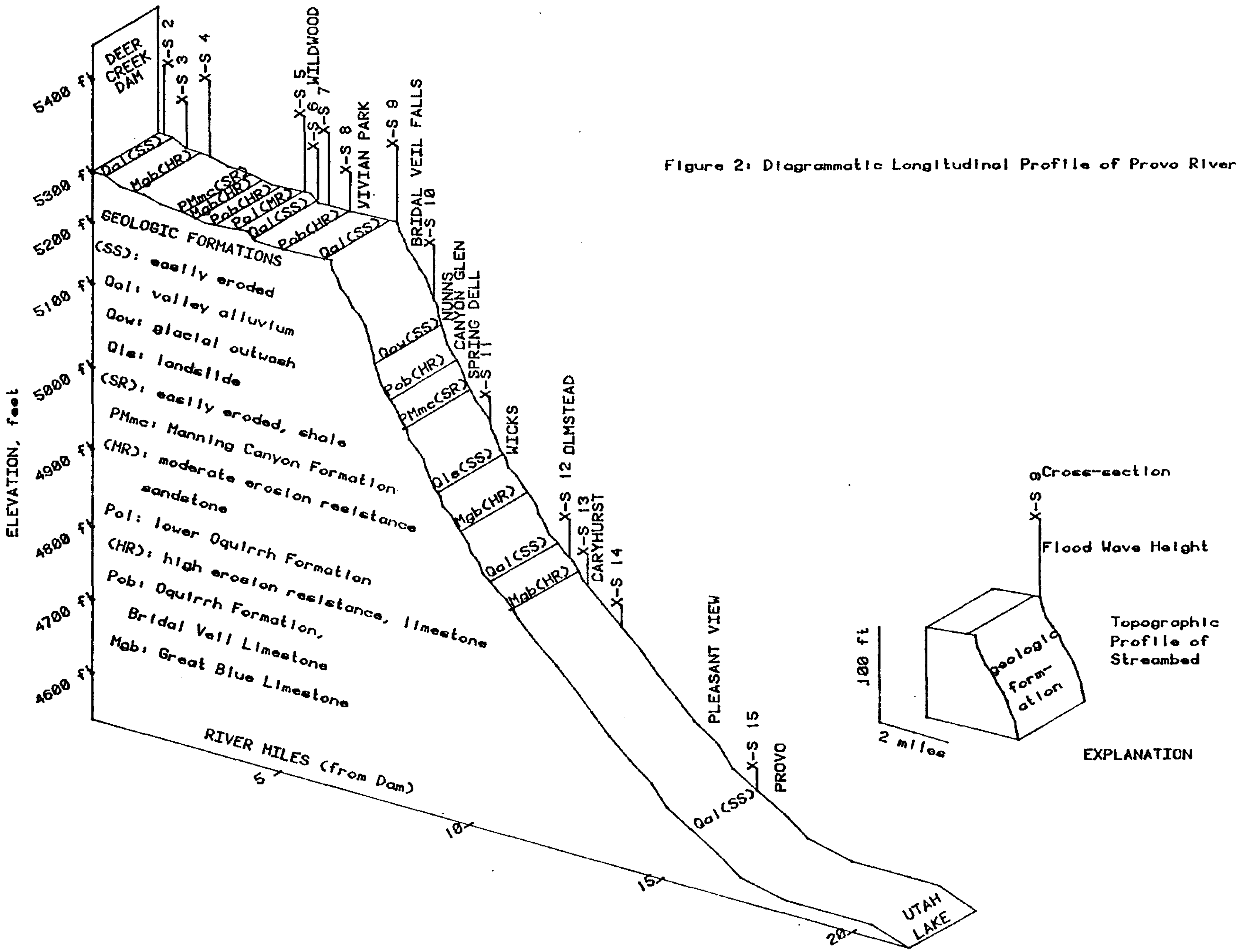

Figure 2: Diagrammatic Longitudinal Profile of Provo River

fill (stream deposit), Qow is glacial outwash (glacial sediments deposited by meltwater), and Qls is a landslide deposit. The first letter or symbol is an abbreviation for the age of the unit, i.e., Q = Quaternary, M = Mississippian, P = Pennsylvanian, PM = Late Mississippian/Early Pennsylvanian.

The erosion resistance of geologic units is a function of: 1) age, younger sediments or rocks are normally less lithified and thus more easily eroded; 2) rock type, in a semi-arid climate (the average annual precipitation at Deer Creek Dam is 23 inches, and at Provo and Utah Lake is 16 inches) limestone is very resistant, and will erode into massive blocks the size of which may be controlled by "joints" (fractures in rock caused by similar tectonic forces that produce faults but which do not result in the slippage characteristic of faults), sandstone has moderate resistance, and shale is relatively soft; and 3) density of faulting, an area of intense faulting will have more crushed rock which is easier to erode. The geologic units shown on figure 2 are in the immediate vicinity of the streambed. It is not known how thick the streambed (Quaternary) deposits are in the channel but for a dam failure flood discharge, such as described in this report, the channel in Provo River Canyon is likely to be scoured to bedrock throughout its length. Shroba (1979) reports that the Big Thompson Canyon flood of July 31, 1976 scoured the creeks to bedrock for the length of the canyon, with a flood discharge only 4 percent (31,200 sec.-ft.) of the discharge postulated in this report (845,619 sec.-ft.). Silt, sand, and gravel will be available for flood transport in varying proportions from all the Quaternary deposits along Provo River Canyon. Larger blocks will come from bedrock, with limestone yielding the largest blocks.

HYDRODYNAMIC ANALYSIS

Potential causes of dam failure include overtopping of flood waters over the dam crest, damage to the structure or foundation due to earthquake shaking, or foundation failure due to piping. Earth dams, such as Deer Creek Dam, may develop a breach that enlarges gradually due to overtopping or piping. The time required for the enlargement of the breach to its maximum size (resulting in the peak flood discharge) may be a few minutes or several hours depending on a multitude of factors including reservoir storage and depth of water behind the dam at the time of failure. Peak depth of flood waters and time to peak discharge just below the dam depend on the breach size, shape, and development time among other factors.

In order to produce an inundation overlay and data layer for a seismic hazard zonation model a worst-case scenario is assumed. The maximum inundated area along the Provo River due to a failure of Deer Creek Dam is utilized. The dam breach is equal to the size of the dam. The reservoir is assumed to be full. Inflow to the reservoir will not be considered because it is minor (less than 1 percent) compared to the magnitude of the dam failure flood discharge. Butler (1966) gives the maximum discharge for the Provo River directly upstream from the reservoir to be approximately 1700 sec.-ft., 0.2 percent of the calculated flood-wave discharge at the dam (845,619 sec.-ft.) due to a hypothetical dam failure. Tributary inflow downstream from the dam was not considered because it, also, is minor (less than 0.1 percent) compared to the calculated dam failure flood discharge.

Emergency plans for evacuation and shelter require not only the geographical extent of flooding but also the minimum amount of time available for evacuation. Because the maximum flood and minimum travel time is desired for this analysis the entire Deer Creek Dam is assumed to fail instantaneously. This postulated event is believed to be extremely improbable. The following analysis will attempt to show the maximum inundation area along the Provo River from Deer Creek Dam to Utah Lake and the expected flood-wave arrival time at various localities assuming the worst conceivable scenario.

The procedures used for estimating peak discharge at the dam and the attenuation of the flood-wave discharge as it moves downstream are based on Bureau of Reclamation 'Guidelines for Defining Inundated Areas Downstream from Bureau of Reclamation Dams' (1982). The Bureau of Reclamation equation for estimating peak discharge at the dam, in sec.-ft., is: $Q = 75(D)^{1.85}$, where Q is the peak discharge and D is the depth of the water in feet behind the dam at the time of failure which, in this study, is equal to the design hydraulic height of Deer Creek Dam, 155 feet. The calculated peak discharge, Q, using this equation is 845,619 sec.-ft. The equation for estimating downstream discharge attenuation, Qx, is: $Qx = 10^{(\log Q - 0.01x)}$, where Qx is the calculated peak discharge in sec.-ft., x miles below the dam. The equations for Q and Qx are empirical and were derived from data compiled by the Bureau of Reclamation (1982).

Cross-sections were drawn at intervals along the valley to characterize the hydraulic properties of the valley, for example at constrictions or change in slope, in order to accurately determine the inundated areas along the river and to determine the extent of potential flood water encroachment on geologic hazards such as landslides. The shape of each cross-section was approximated by trapezoidal sub-sections to simplify determination of cross-sectional area and wetted-perimeter (cumulative length of channel sides and bottom in contact with floodwater). Many analyses assume the wetted perimeter is basically the same as the width of the channel, however, because of the large-scale maps that were available the channel sides were considered as part of the wetted perimeter. Each trapezoidal sub-section was defined by a top- and bottom-width and their respective elevations. The bottom-width of the initial trapezoidal sub-section for each cross-section is the width of the streambed.

The discharge for each trapezoidal cross-section was calculated using Mannings equation for open-channel flow. The depth in the cross-section approximation is increased until the calculated discharge is contained.

Mannings equation calculates cross-sectional discharge (Qs) as a function of: A) n, a parameter characterizing net channel roughness, which is assumed to be 0.035 in this study, the average value for natural channels according to Linsley (1975); B) s, the topographical gradient of the streambed from the closest upstream cross-section in vertical feet/horizontal feet; C) A, the area of the cross-section in square feet; and D) R, the hydraulic radius of the cross-section, in feet (the cross-sectional area A, divided by the wetted-perimeter of the cross-section). The discharge through the cross-section, Qs, is calculated from Mannings equation where $Qs = (1.49/n)(s)^{1/2}(R)^{2/3}(A)$, in sec.-ft. Code for a hand-held calculator used to compute the peak flood-level elevation at each cross-section. Results compared favorably with the National Weather Service (NWS) Simplified Dambreak Program (SMPDBK). This elevation defines the maximum inundation at the cross-section.

The peak flood elevations and inundated areas between cross-sections is subject to interpretation and must be interpolated using hydraulic logic from values calculated at cross-sections. In a straight channel the water surface is relatively level, i.e., the water surface is at the same elevation on both banks. A curved pathway such as in a natural meander introduces a centrifugal force on the flowing water mass resulting in higher water on the outside of the bend and lower water on the inside of the bend than would occur with a straight channel. Flood waters tend to back upstream as a result of valley constrictions. Increased channel-bottom resistance also increases depth of flood waters due to the fact that vegetation or buildings reduce the velocity of flood waters.

The average velocity of flow at the cross-section, in feet/second, is equal to the discharge, Qs, divided by the area, A. Travel times of the flood crest are estimated because of the number of variables that can influence velocity.

The topographic base maps used are from the Utah State Department of Transportation (UDOT) and Utah County Flood Control Office. The UDOT maps are at a scale 1 inch = 100 feet with a contour interval of 2 feet and cover the Provo River Canyon from Deer Creek Dam to the canyon mouth, about 11 river miles. The Utah County maps have a contour interval of 5 feet, a scale 1 inch = 500 feet, and cover the drainage area from the canyon mouth to Utah Lake, about 9 river miles. It should be noted that the topographic maps used were drafted before the recent (1983-84) increase in precipitation in the Provo River area, therefore the topography of the river valley may have changed slightly.

Sixteen cross-sections, from #1 at the base of Deer Creek Dam spillway to #16 at Utah Lake State Park, were drawn across the Provo River at specific locations (plate 1). Flood-wave crest elevations have been calculated and plotted on plate 1 for all cross-sections except 1 and 16. Cross-section 1 (river mile 0.00) is at the base of the dam 0.16 miles upstream from 2. Cross-section 16 (river mile 20.14) extends from the Utah Lake shoreline on one end to the shoreline on the other end of the section across the Provo River delta. By the time the flood-wave arrives at cross-section 16 it will have exceeded the width of the section therefore the height cannot be calculated. Cross-sections 2, 4, 5, 7, 12, 13, 14, 15 were located to characterize Provo River Canyon hydraulic parameters. Populated areas in the canyon and on the flood plain are covered by cross-sections 2, 3, 6, 8, 10, 11, 13, 14, and 15 (note: some cross-sections are multi-purpose). Cross-sections 9, 10, 11 are at locations of landslides and glacial outwash. Cross-section widths range from 419 feet (7) to 6464 feet (15) and the depth of the flood-wave ranges from 25 feet at section 15 (the widest cross-section) to 83 feet at cross-section 9 which has the most gentle channel-bed slope along the study reach, 10 ft/mile. Just downstream, at cross-sections 10 and 11, the slopes are 83 ft/mile and 90 ft/mile, the steepest slopes. Cross-section 10 will have the highest average velocity of flood waters, 36 mph (53 ft/s). All cross-section plots showing the flood-wave crest elevation, geology, and diagrammatic topography are in appendix A. Table A-1 in appendix A is a compilation of relevant data used for calculations for each cross-section. All top-widths used in the hydraulic calculations were picked at a topographic threshold if evident (where a channel suddenly widens as the water level rises), or to characterize the slope of valley walls. The smallest top-width and lowest elevation of the cross-section represent the present channel width and streambed elevation as estimated within the contour interval of the base maps.

DISCUSSION

Plate 1 shows the extent of the inundation of Deer Creek Reservoir waters from Deer Creek Dam to Utah Lake. Table 1 lists known obstructions in the study area, their height above the streambed, and the height of the expected flood-wave above the obstruction. Examples of obstructions include: bridges (foot, vehicle, or railroad), weirs, diversion dams, viaducts, and abutments of dismantled structures. The only feature that would not be overtopped by the calculated flood-wave is the bridge at West Center Street (river mile 20.05), however, if the flow velocity is greater than 3 mph (hydraulic calculations indicate that flow velocities would be approximately 10 mph) the

Table 1. List of Provo River Flood Obstructions
(from Corps of Engineers, 1971 & 1972)

Obstruction	River Mile	Top Elev. (ft.)	Approx. Flood -wave Crest Elev. (ft.)	Approx. Flood Height Above Feature (ft.)
Vehicle bridge	0.40	5280	5330	50
Foot bridge	0.84	5261	5310	49
Foot bridge	0.88	5261	5310	49
Railroad bridge	2.77	5232	5310	78
Vehicle bridge, Vivian Park	5.15	5197	5220	23
Union Aqueduct diversion	6.11	5194	5270	76
Foot bridge	6.55	5159	5220	61
Foot bridge, Bridal Veil Falls	7.22	5110	5165	55
HWY 189 bridge	7.63	5060	5110	50
Foot bridge	7.76	5042	5080	38
Railroad bridge	8.35	4995	5020	25
Vehicle bridge	9.88	4897	4910	13
Murdock diversion dam	10.00	4886	4900	13
Railroad bridge, abandoned	10.88	4827	4850	23
Timpanogos Canal diversion	10.89	4820	4850	30
Upper Union Canal diversion	10.90	4816	4850	34
North Union Canal diversion	10.94	4815	4845	30
Unnamed canal diversion	10.98	4820	4845	25
8th North, Orem bridge	11.07	4821	4840	19
Railroad bridge	11.27	4800	4825	25
West Union canal diversion	11.36	4791	4820	29
Carterville Road bridge	11.54	4791	4810	19
Center St., Orem abutment	12.21	4745	4770	25
3700 N, Provo bridge	13.33	4701	4715	14
Riverside Golf Course bridge	14.33	4650	4665	15
Lake Bottom canal diversion	14.55	4630	4655	25
Lower Union Canal diversion & bridge	14.75	4623	4645	22
BYU diagonal: east	14.96	4620	4635	15
BYU diagonal: west	14.98	4619	4635	16
HWY 89-91 bridge	15.60	4590	4605	15

Table 1. List of Provo River Flood Obstructions - Continued.

Columbia Lane bridge	15.72	4592	4595	3
Weir	15.73	4581	4595	14
9th No, Provo bridge	16.10	4573	4585	12
8th No, Provo bridge	16.19	4572	4580	8
D&RGW rail abutments	16.94	4527	4555	28
D&RGW rail bridge	16.98	4539	4550	11
U.P. railroad bridge	17.04	4543	4550	7
I-15 HWY bridge	17.12	4537	4545	8
Weir	17.15	4518	4545	27
HWY 114 bridge	17.42	4523	4535	12
West Center St. bridge	20.05	4497	4495	-3
Utah Lake State Park bridge	20.17	4490	4495	5

bridge piers could be washed out due to erosion of surrounding fill (Corps of Engineers, 1972). Another type of obstruction that occurs in the study area is the embankment of Interstate 15. Although it is estimated that the flood waters may overtop the embankment (table 1) some water would back up on the upslope side of the embankment and would flow to the northwest and southeast (plate 1). Once this water reaches an overpass it would flow through the overpass at a high velocity, particularly if the surface is paved. The "breaks" in the I-15 embankment through which flood waters would flow include the overpass over the railroad tracks about 9th North in Provo, the Center Street overpass, and the intersection of University Avenue and Interstate 15. The ponding upslope of the I-15 embankment would likely extend well into Provo. Below the city and the embankment the flood waters would fan out and deposit debris across the Utah Lake plain.

As a result of flood waters from a Deer Creek Dam failure, the water level in Utah Lake may temporarily rise above an elevation of 4490 foot. The projected maximum water surface elevation increase in Utah Lake would be about 8 inches. If the Jordan River gates were open it is likely that areas along the Jordan River would be flooded although the consequent rise in the Great Salt Lake would be minimal.

Water flowing out of the canyon mouth below the constriction at cross-section 12 would spread out between two bluffs and, as the flooded channel effectively widens below the mouth of Provo River Canyon, flow velocities would steadily decrease. The average velocity of flood waters through cross-section 12 (narrow canyon mouth) would be about 30 mph. As the flooded channel widens the velocities would decrease progressively to 10 mph at section 15 in Provo City. Once the flood waters leave cross-section 15 (river mile 15.63) they would spread out because they are no longer contained by the river bluffs. Locally the velocity would be higher, for example, over paved streets, through local constrictions, etc. The velocities in the bluff area would be of the same magnitude as those in the steepest reaches of the Big Thompson Canyon flood in Colorado in 1976 (Shroba, 1979). With such high velocities one would expect similar damage, that is, vehicles smashed beyond recognition, wood frame houses torn off foundations, masonry buildings destroyed by debris acting as battering rams, deposition of very large-diameter debris (natural and man made) in bars nearly 20 feet thick. All transportation routes within the bluff area (cross-sections 12 to 15) and within the Provo River Canyon (cross-sections 1 to 11) would be severed. The bluffs themselves would be undercut and slopes would fail severing the canals on top. The canals near the mouth of Provo River Canyon would probably be breached early in the flood and therefore would not likely route flood water beyond the postulated area of inundation. The Olmstead hydropower plant would be taken out of service by the flood waters. It would take about one-half hour, after dam failure for the flood-wave (a 38-foot-high wall of water loaded with diverse debris) to reach the mouth of the canyon.

Upstream, within the Provo River Canyon, the flood waters would scour the canyon to bedrock or below depending on local conditions. Sediment that has been picked up is usually deposited just downstream in the next area of slack water, except for floating material that wasn't tangled up. The flood waters would undercut most of the highway fill and railroad fill, and near cross-section 9, would sever the Salt Lake City Aqueduct and the Union Aqueduct. All Provo River Canyon communities and facilities would be flooded. The flood waters would back up approximately 1200 feet into North Fork (at Wildwood) and probably would back 1000 feet up the South Fork into Vivian Park. New landslides would be initiated due to bank undercutting and channel scour by the flood and old landslides would be rejuvenated.

It would take approximately 10 minutes (after dam failure) for the flood-wave to reach Wildwood, the first vehicle escape route out of the canyon. In about 15 more minutes the flood-wave would be at the canyon mouth and approximately 90 minutes after the dam failure flood waters would reach Utah Lake. The average velocity of the flood waters from Deer Creek Dam to Utah Lake would be approximately 15 mph.

Facts that should be considered while planning emergency responses should include the following:

A) People in the Provo River Canyon should not try to drive out of the canyon, but instead should head for high ground. A warning system should be installed in the canyon, one that is not dependent on normal communication channels (telephone or CB). People in the canyon will have less than 1/2 hour to save themselves.

B) Refugee areas would likely be on the northwest and southeast sides of Provo River, the bench at Orem and the BYU campus plateau. North-south highways will be severed. The evacuation paths should be east-west. Even after flood waters have subsided normal transportation routes will be clogged with sediment and debris.

C) Evacuation time below the canyon mouth would range from one-half to one hour.

D) All lifelines (phone, sewer, water, power, gas) may be severed or contaminated. The sewer treatment plants (Timpanogos, Orem, & Provo City) may become inoperative. Administrative operations may have to be moved from Provo.

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APPENDIX

Table A-1 consists of the top-widths, elevations, slope, and discharge used for the calculations of Flood-wave crest parameters for cross-sections #2 through #15. Diagrammatic representations of cross-sections #2 through #15 follow below the table.

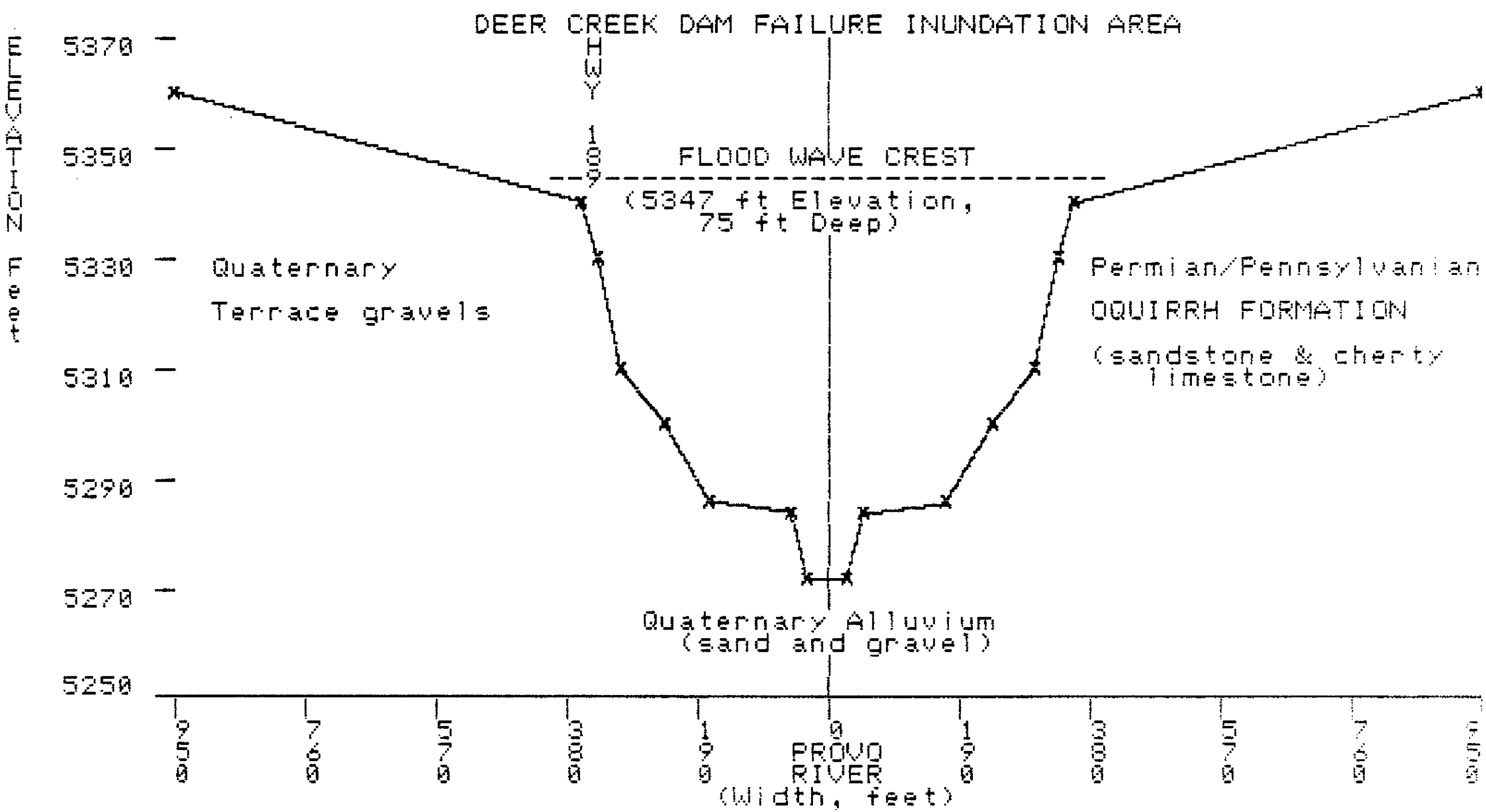
Table A-1. Cross-Section Data - Continued

	TOP WIDTH (FT)	ELEVA-TION (FT)	
	* 35	5178	
	75	5190	
CROSS-SECTION #9	100	5192	FLOOD-WAVE CREST
RIVER MILE = 6.26	120	5198	ELEVATION = 5261 feet
SLOPE=0.0019 ft/ft	270	5200	PEAK DEPTH = 83 feet
PEAK DISCHARGE,Qx= 732,107cfs	298	5208	ARRIVAL TIME = 20 min#
	670	5250	AVE.VELOCITY = 15 mph
	800	5270	
CROSS-SECTION #10	* 38	5096	FLOOD-WAVE CREST
RIVER MILE = 7.25	55	5104	ELEVATION = 5153 feet
SLOPE=0.0157 ft/ft	120	5108	PEAK DEPTH = 57 feet
PEAK DISCHARGE,Qx= 715,607cfs	210	5114	ARRIVAL TIME = 22 min#
	263	5130	AVE.VELOCITY = 36 mph
	440	5160	
CROSS-SECTION #11	* 66	4968	FLOOD-WAVE CREST
RIVER MILE = 8.68	495	4972	ELEVATION = 4993 feet
SLOPE=0.0017 ft/ft	660	4974	PEAK DEPTH = 25 feet
PEAK DISCHARGE,Qx= 692,428cfs	746	4990	ARRIVAL TIME = 24.5 min#
	790	4993	AVE.VELOCITY = 29 mph
	* 33	4826	FLOOD-WAVE CREST
CROSS-SECTION #12	50	4828	ELEVATION = 4864 feet
RIVER MILE = 10.75	255	4834	PEAK DEPTH = 38 feet
SLOPE=0.0013 ft/ft	385	4836	ARRIVAL TIME = 28.5 min#
PEAK DISCHARGE,Qx= 660,199cfs	453	4850	AVE.VELOCITY = 31 mph
	502	4870	
CROSS-SECTION #13	* 40	4796	FLOOD-WAVE CREST
RIVER MILE = 11.23	80	4805	ELEVATION = 4828 feet
SLOPE=0.0118 ft/ft	310	4810	PEAK DEPTH = 32 feet
PEAK DISCHARGE,Qx= 652,942cfs	523	4814	ARRIVAL TIME = 30 min#
	1265	4816	AVE.VELOCITY = 20 mph
	1340	4825	
	1378	4850	
CROSS-SECTION #14	* 75	4751	FLOOD-WAVE CREST
RIVER MILE = 12.11	650	4760	ELEVATION = 4774 feet
SLOPE=0.0097 ft/ft	1620	4764	PEAK DEPTH = 23 feet
PEAK DISCHARGE,Qx= 639,845cfs	3200	4800	ARRIVAL TIME = 33.5 min#
			AVE.VELOCITY = 16 mph
CROSS-SECTION #15	* 80	4575	FLOOD-WAVE CREST
RIVER MILE = 15.63	95	4590	ELEVATION = 4600 feet
SLOPE=0.0095 ft/ft	1270	4594	PEAK DEPTH = 25 feet
PEAK DISCHARGE,Qx= 590,031cfs	6430	4596	ARRIVAL TIME = 54.5 min#
	6464	4600	AVE.VELOCITY = 10 mph
	6624	4625	

Table A-1. Cross-Section Data

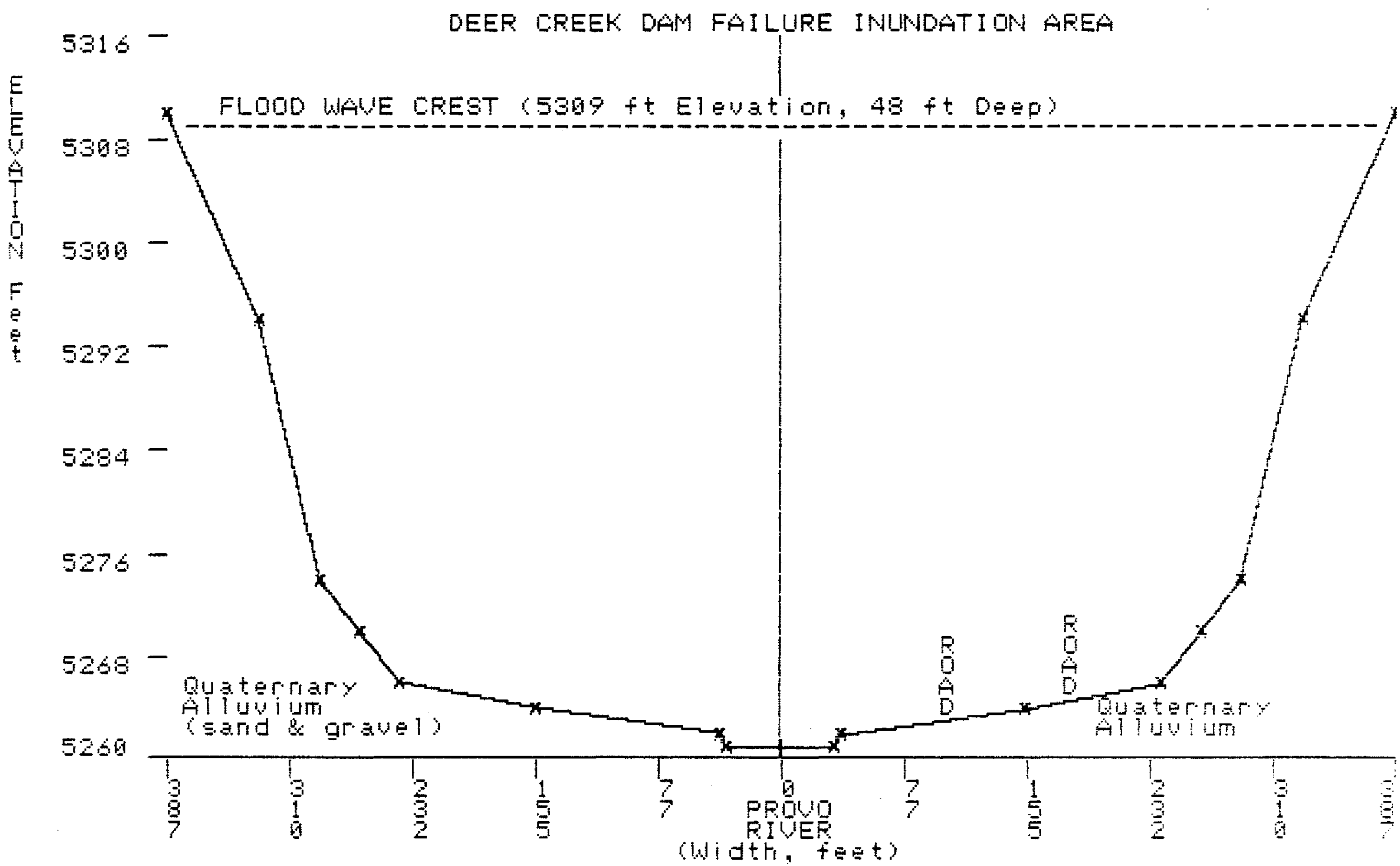
	TOP WIDTH (FT)	ELEVATION (FT)	
	* 55	5272	
	103	5284	
CROSS-SECTION #2	340	5286	FLOOD-WAVE CREST
RIVER MILE = 0.16	475	5300	ELEVATION = 5347 feet
SLOPE=0.0024 ft/ft	600	5310	PEAK DEPTH = 75 feet
PEAK DISCHARGE,Qx= 842,509cfs	670	5330	ARRIVAL TIME = 0.5 min#
	715	5340	AVE.VELOCITY = 15 mph
	1900	5360	
	* 67	5261	
	75	5262	
CROSS-SECTION #3	307	5264	FLOOD-WAVE CREST
RIVER MILE = 0.74	480	5266	ELEVATION = 5309 feet
SLOPE=0.0036 ft/ft	530	5270	PEAK DEPTH = 48 feet
PEAK DISCHARGE,Qx= 831,332cfs	580	5274	ARRIVAL TIME = 2.5 min#
	656	5294	AVE.VELOCITY = 19 mph
	774	5310	
	* 33	5250	
CROSS-SECTION #4	150	5264	FLOOD-WAVE CREST
RIVER MILE = 1.34	335	5288	ELEVATION = 5331 feet
SLOPE=0.0035 ft/ft	420	5314	PEAK DEPTH = 81 feet
PEAK DISCHARGE,Qx= 819,926cfs	550	5316	ARRIVAL TIME = 4 min#
	613	5340	AVE.VELOCITY = 21 mph
CROSS-SECTION #5	* 70	5212	FLOOD-WAVE CREST
RIVER MILE = 3.84	160	5218	ELEVATION = 5293 feet
SLOPE=0.0029 ft/ft	238	5226	PEAK DEPTH = 81 feet
PEAK DISCHARGE,Qx= 774,060cfs	293	5250	ARRIVAL TIME = 11min#
	503	5300	AVE.VELOCITY = 21 mph
CROSS-SECTION #6	* 43	5204	FLOOD-WAVE CREST
RIVER MILE = 4.20	188	5208	ELEVATION = 5258 feet
SLOPE=0.0046 ft/ft	340	5211	PEAK DEPTH = 54 feet
PEAK DISCHARGE,Qx= 767,670cfs	485	5240	ARRIVAL TIME = 12.5 min#
	604	5280	AVE.VELOCITY = 23 mph
CROSS-SECTION #7	* 35	5198	FLOOD-WAVE CREST
RIVER MILE = 4.45	190	5209	ELEVATION = 5274 feet
SLOPE=0.0045 ft/ft	268	5230	PEAK DEPTH = 76 feet
PEAK DISCHARGE,Qx= 763,264cfs	340	5260	ARRIVAL TIME = 13 min#
	419	5280	AVE.VELOCITY = 25 mph
CROSS-SECTION #8	* 65	5190	FLOOD-WAVE CREST
RIVER MILE = 5.05	90	5192	ELEVATION = 5231 feet
SLOPE=0.0029 ft/ft	570	5196	PEAK DEPTH = 41 feet
PEAK DISCHARGE,Qx= 752,792cfs	913	5210	ARRIVAL TIME = 15 min#
	1019	5250	AVE.VELOCITY = 16 mph

(Note: * = streambed width and elevation, # = approximate travel time from dam)



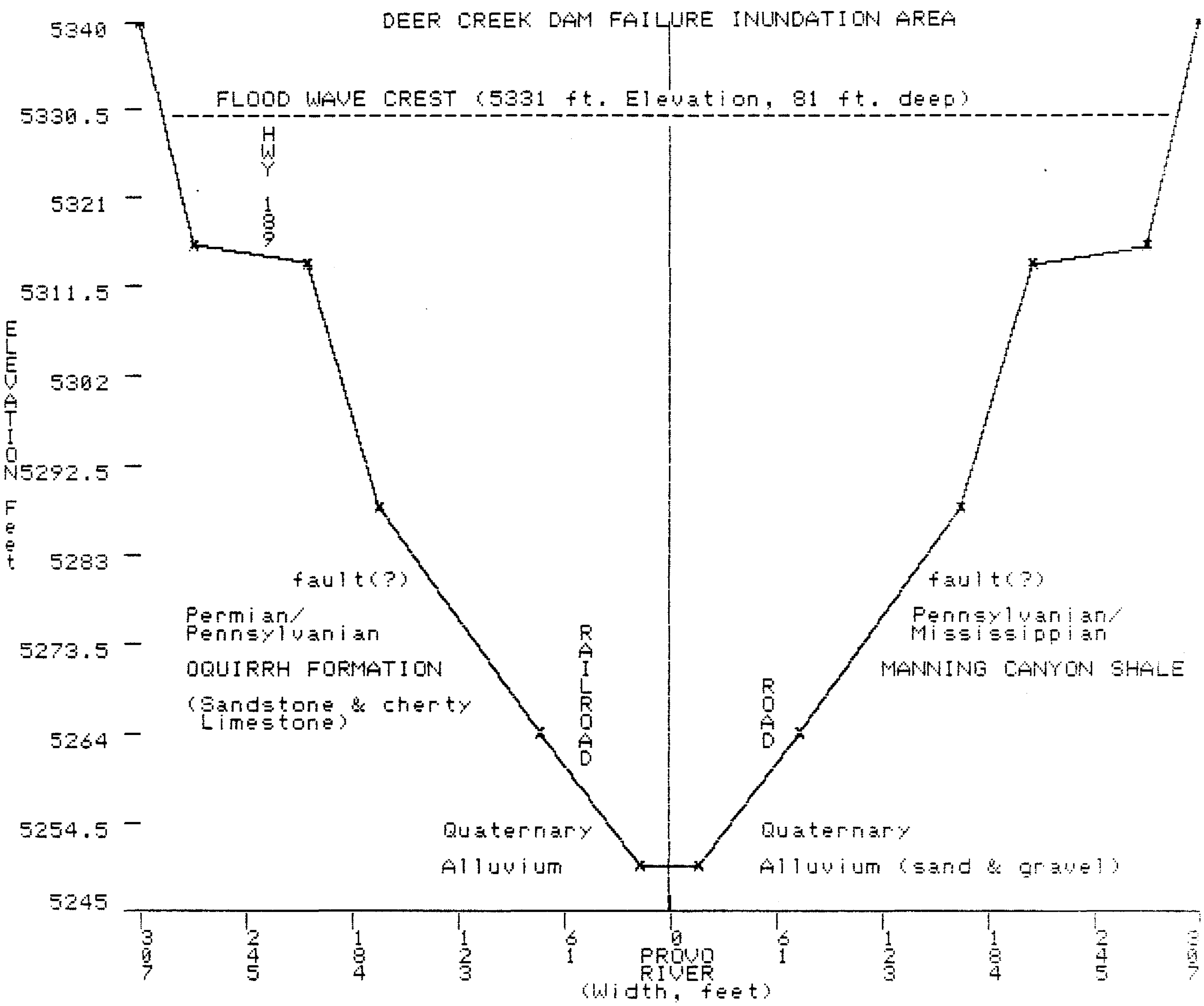
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 2: River Mile=0.16

Scales: Horizontal= 1:3281, Vertical= 1:410 ;Vertical Exaggeration=8x



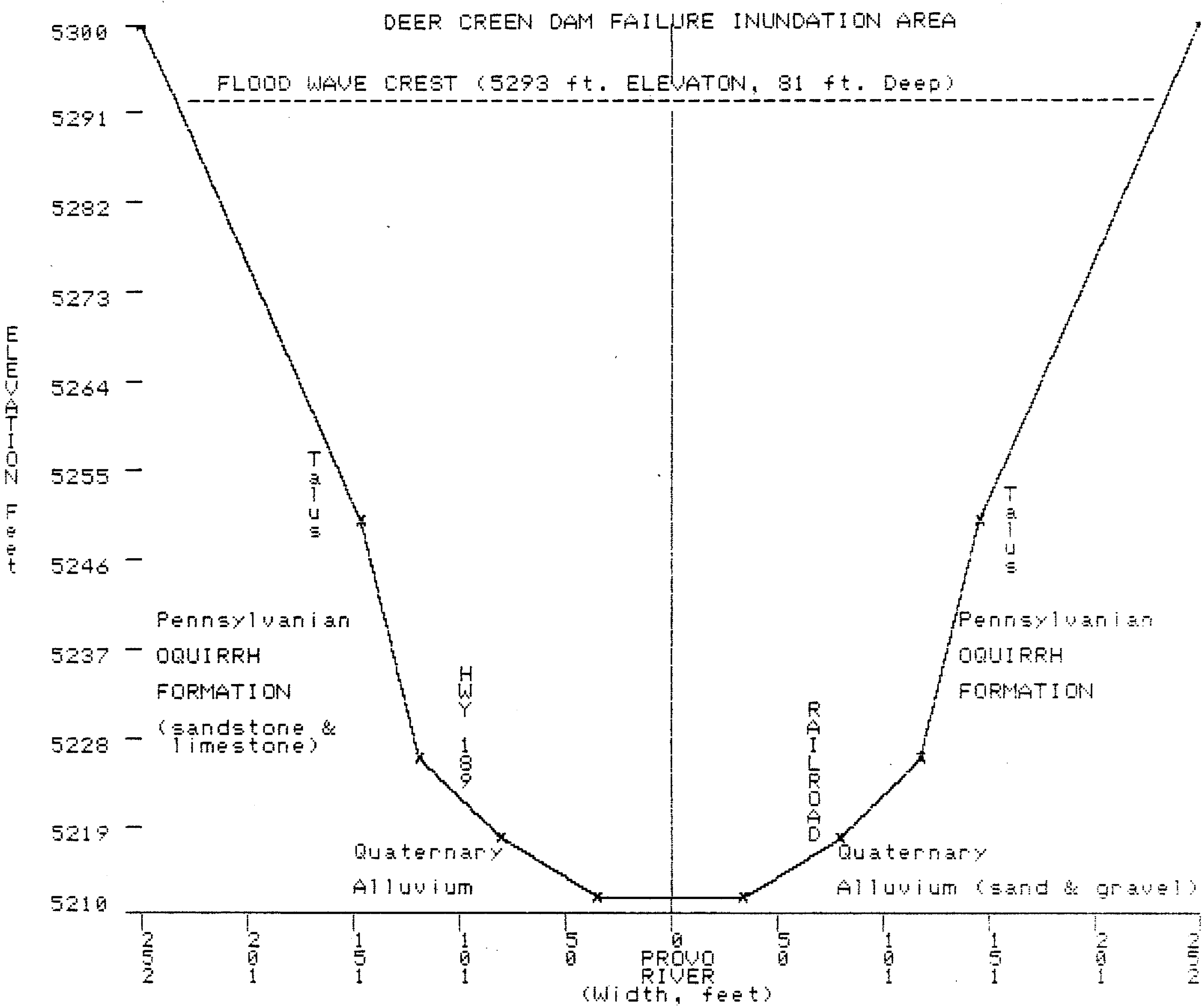
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 3: River Mile=0.74

Scales: Horizontal= 1:1333, Vertical= 1:164 ;Vertical Exaggeration=8x



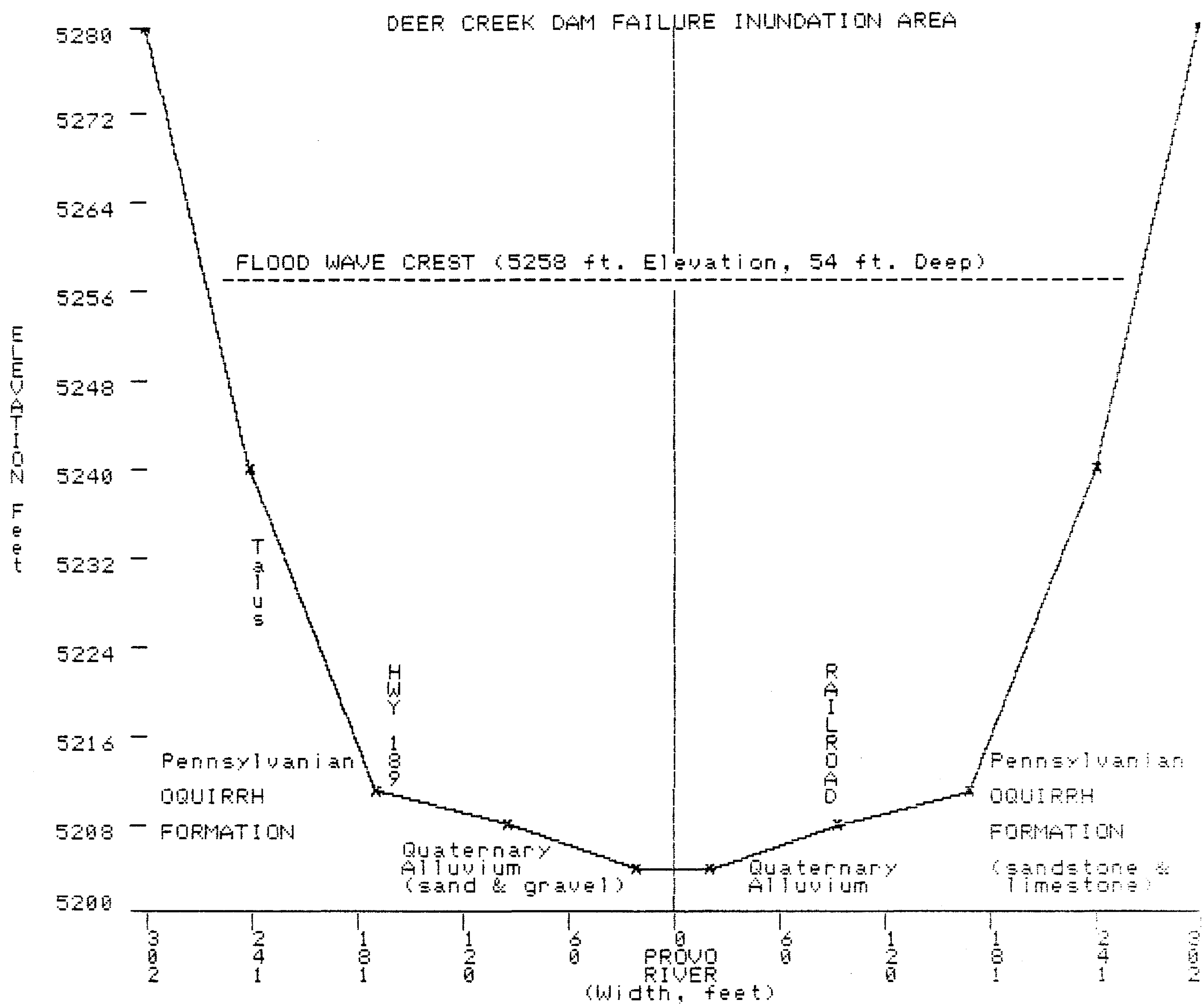
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 4: River Mile=1.34

Scales: Horizontal= 1:1057, Vertical= 1:195 ;Vertical Exaggeration=5x



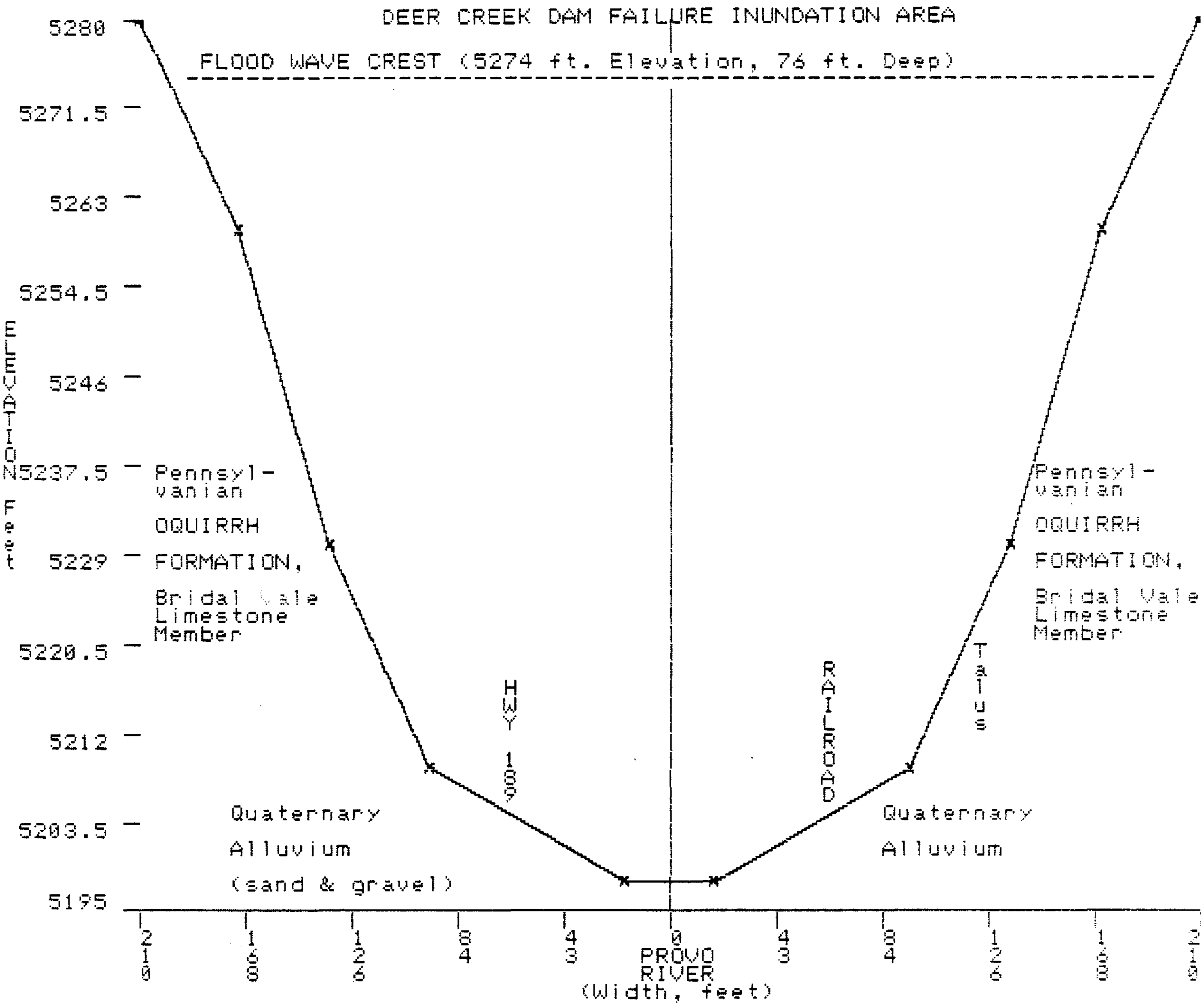
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 5: River Mile=3.84

Scales: Horizontal= 1:1732, Vertical= 1:185 ;Vertical Exaggeration=9x



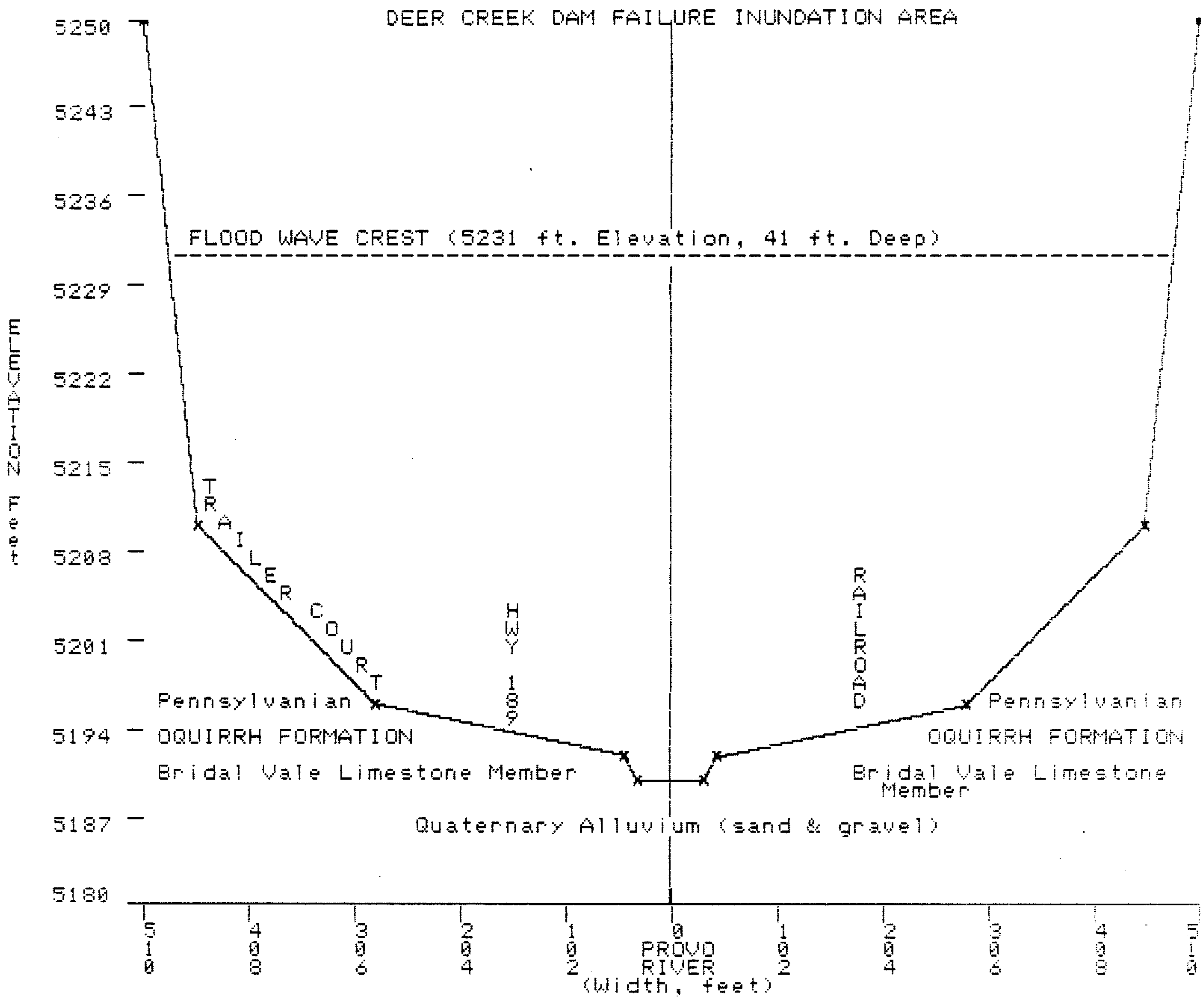
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 6: River Mile=4.2

Scales: Horizontal= 1:1038, Vertical= 1:164 ;Vertical Exaggeration=6x



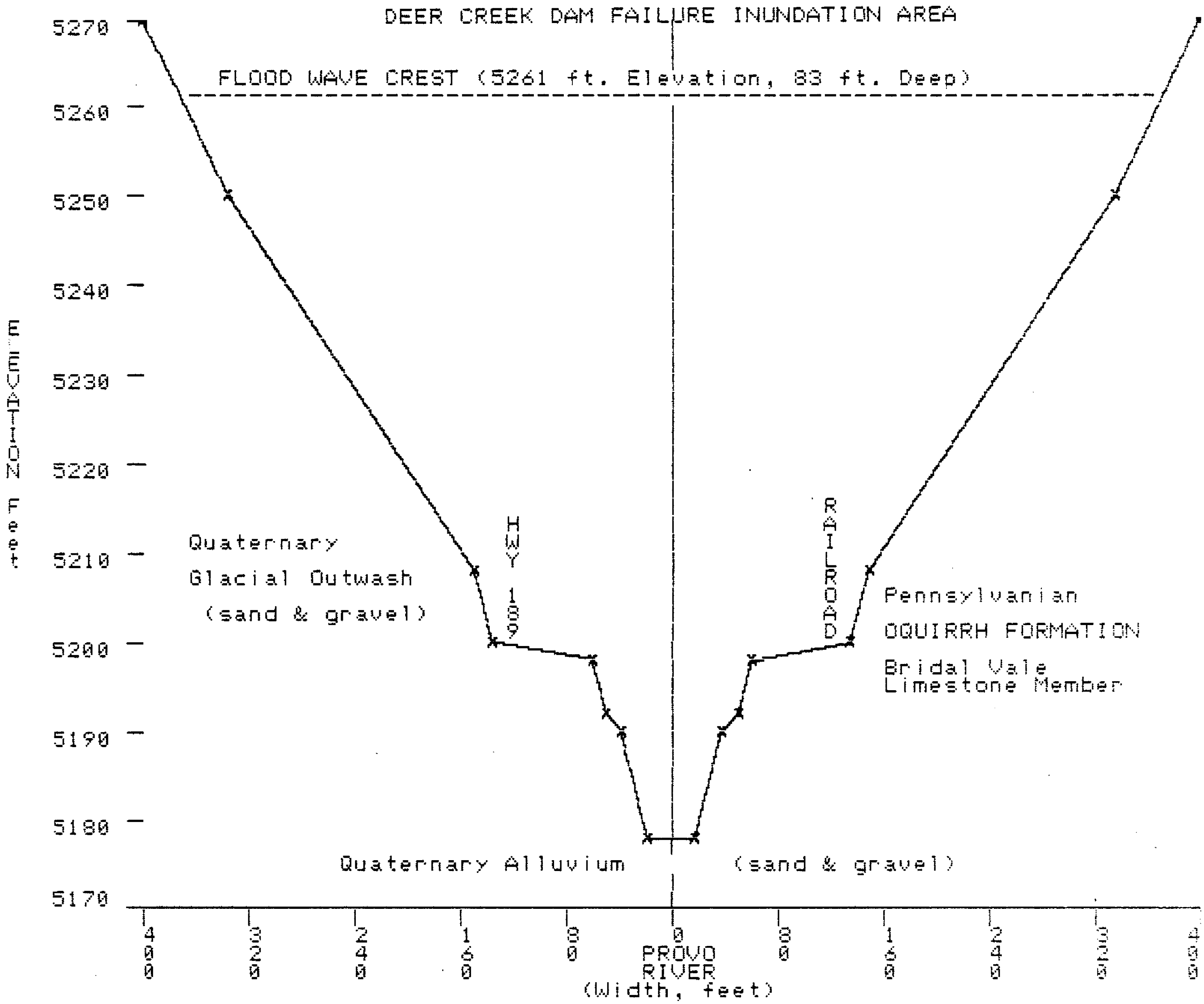
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 7: River Mile=4.45

Scales: Horizontal= 1:724 , Vertical= 1:175 ;Vertical Exaggeration=4x



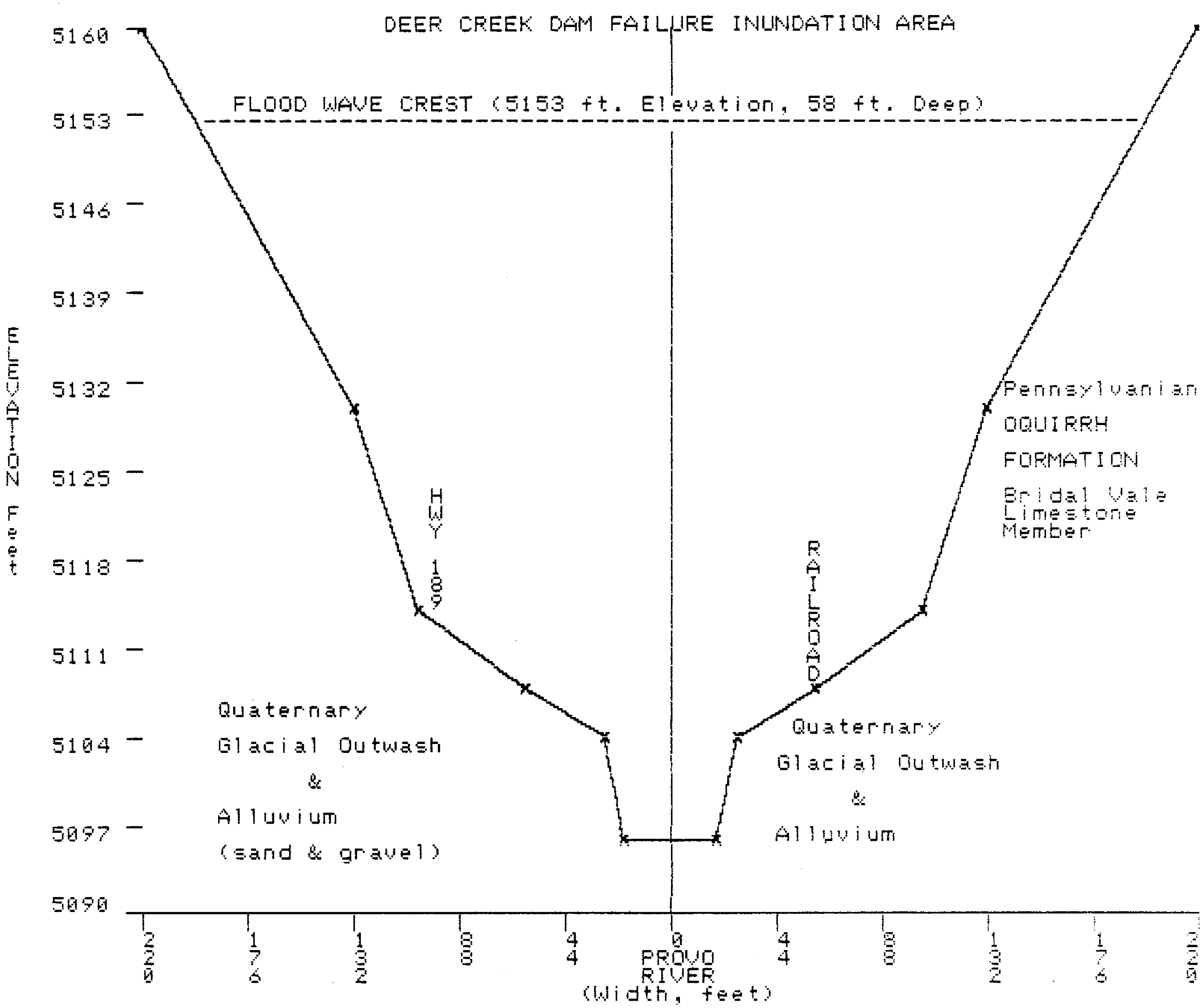
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 8: River Mile=5.05

Scales: Horizontal= 1:1754, Vertical= 1:840 ;Vertical Exaggeration=2x



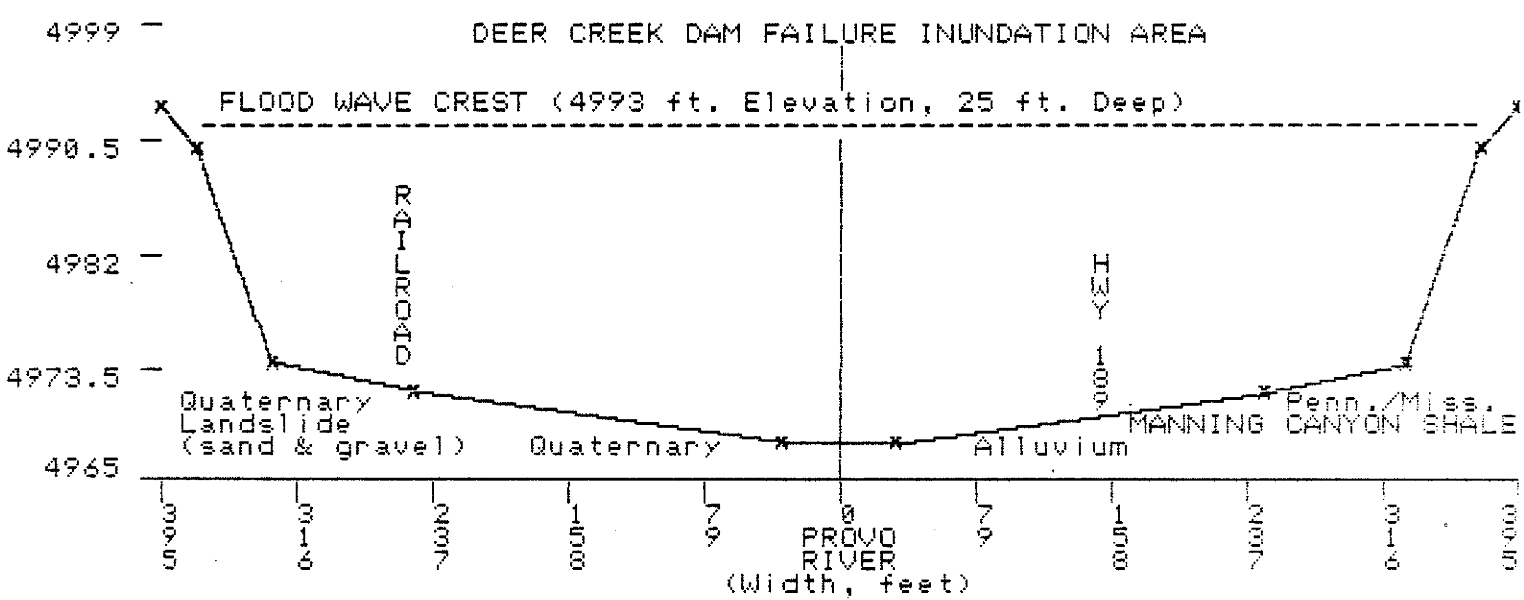
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION # 9: River Mile=6.26

Scales: Horizontal= 1:1375, Vertical= 1:205 ;Vertical Exaggeration=7x



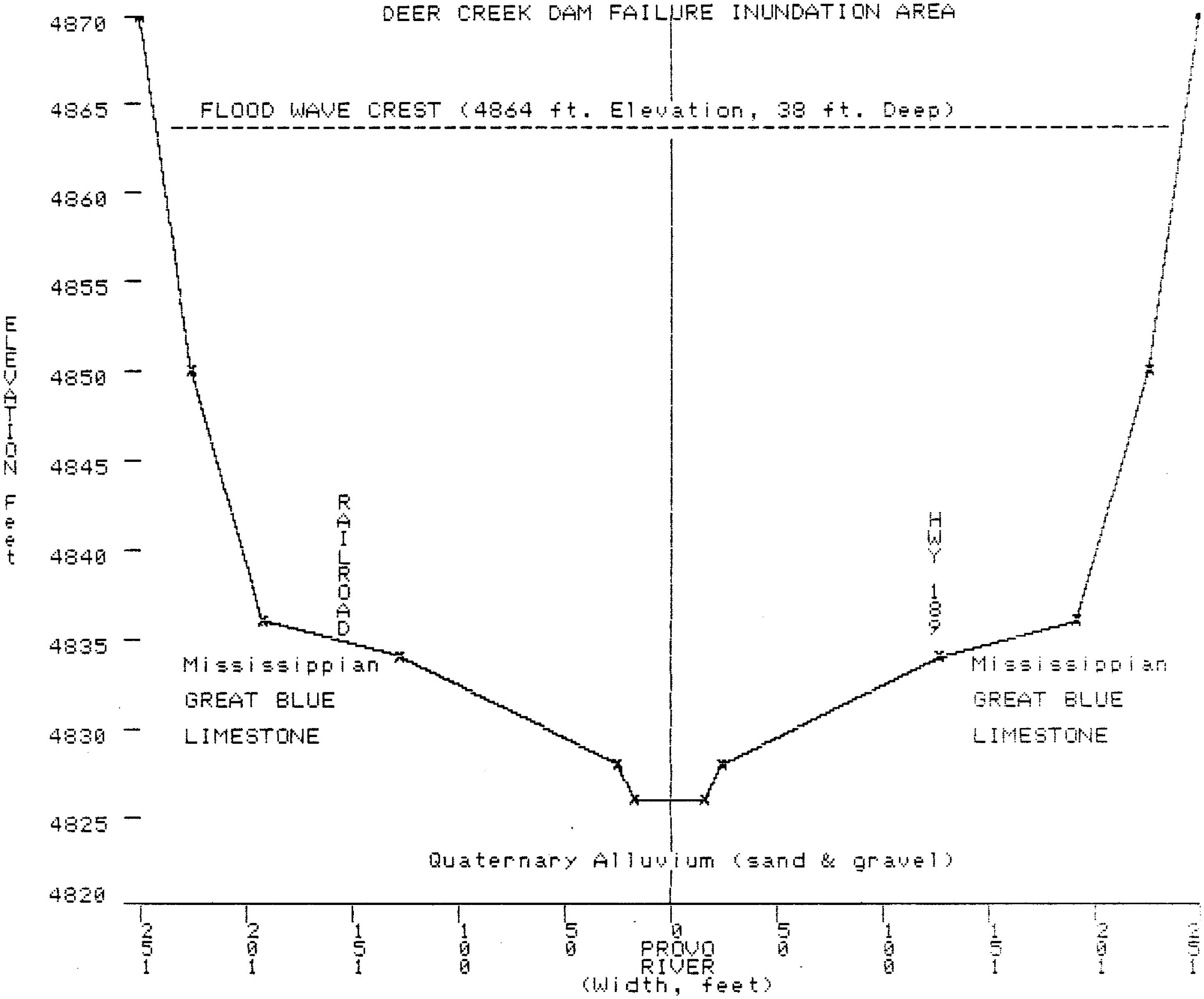
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #10: River Mile=7.25

Scales: Horizontal= 1:756 , Vertical= 1:144 ;Vertical Exaggeration=5x



DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #11: River Mile=8.68

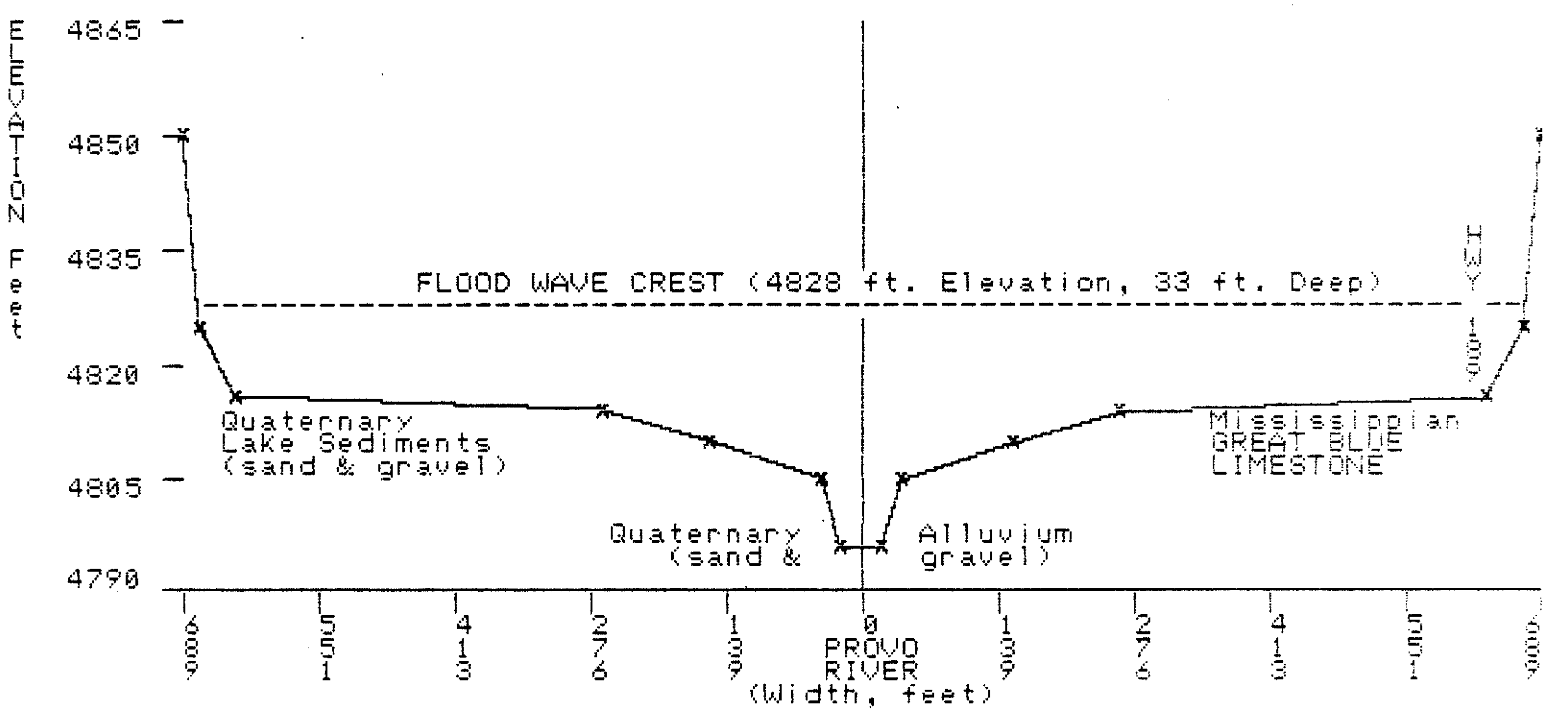
Scales: Horizontal= 1:1362, Vertical= 1:174 ;Vertical Exaggeration=8x



DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #12: River Mile=10.75

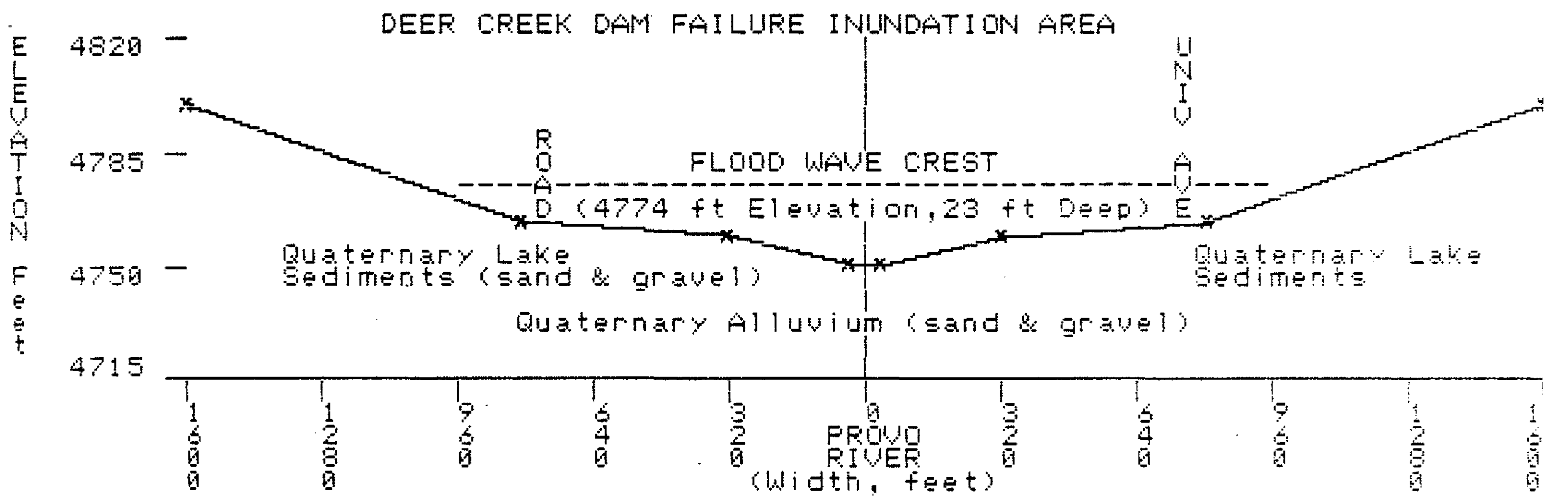
Scales: Horizontal= 1:863 , Vertical= 1:103 ;Vertical Exaggeration=8x

DEER CREEK DAM FAILURE INUNDATION AREA



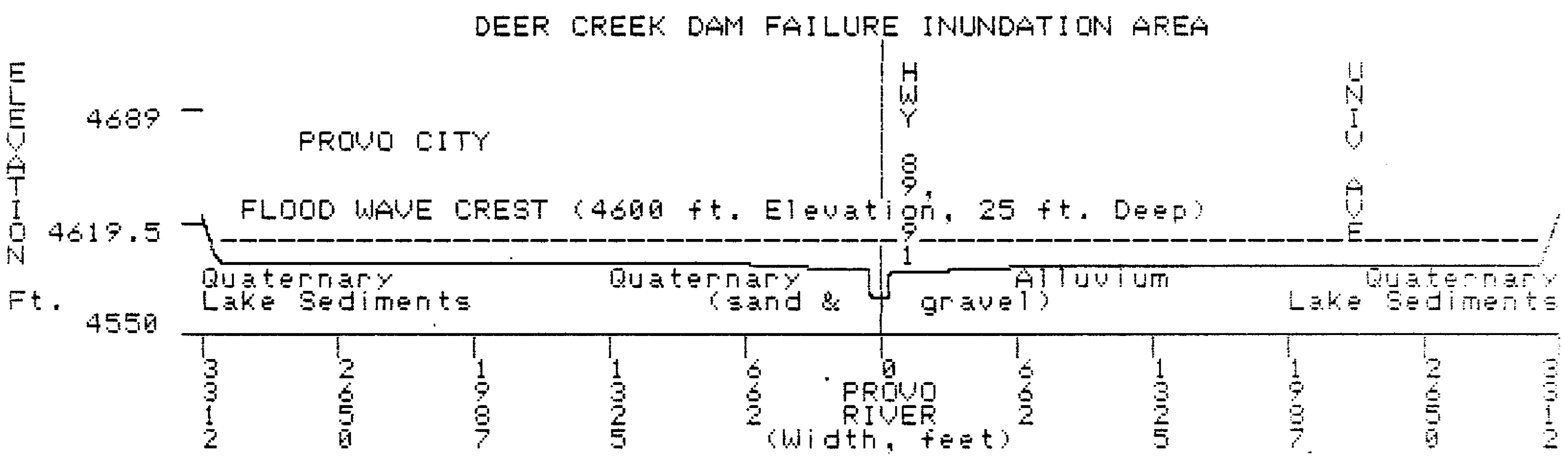
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #13: River Mile=11.23

Scales: Horizontal= 1:2373, Vertical= 1:309 ;Vertical Exaggeration=8x



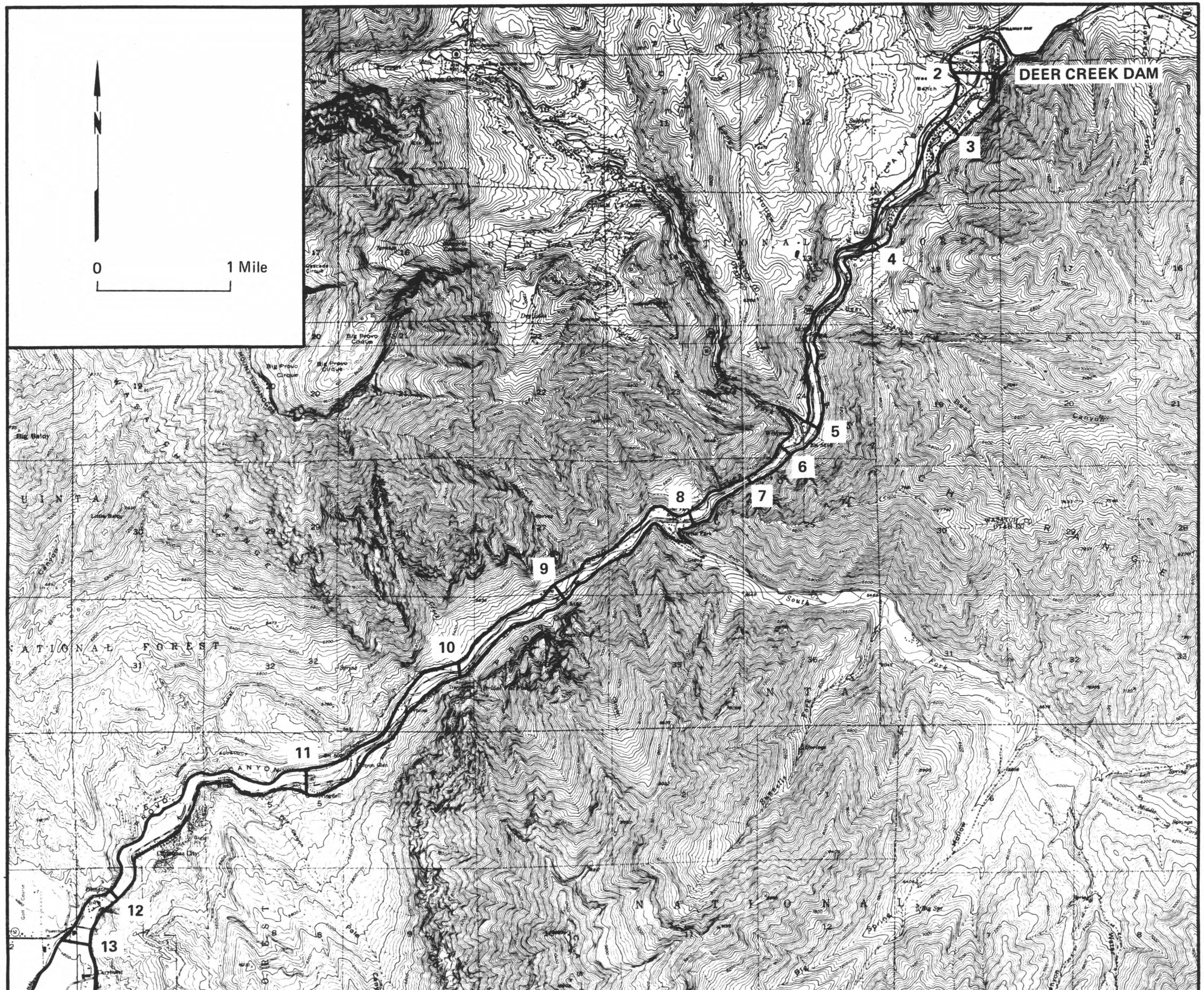
DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #14: River Mile=12.11

Scales: Horizontal= 1:5501, Vertical= 1:718 ;Vertical Exaggeration=8x



DIAGRAMMATIC REPRESENTATION OF CROSS-SECTION #15: River Mile=15.63

Scales: Horizontal=1:11404, Vertical= 1:1426;Vertical Exaggeration=8x



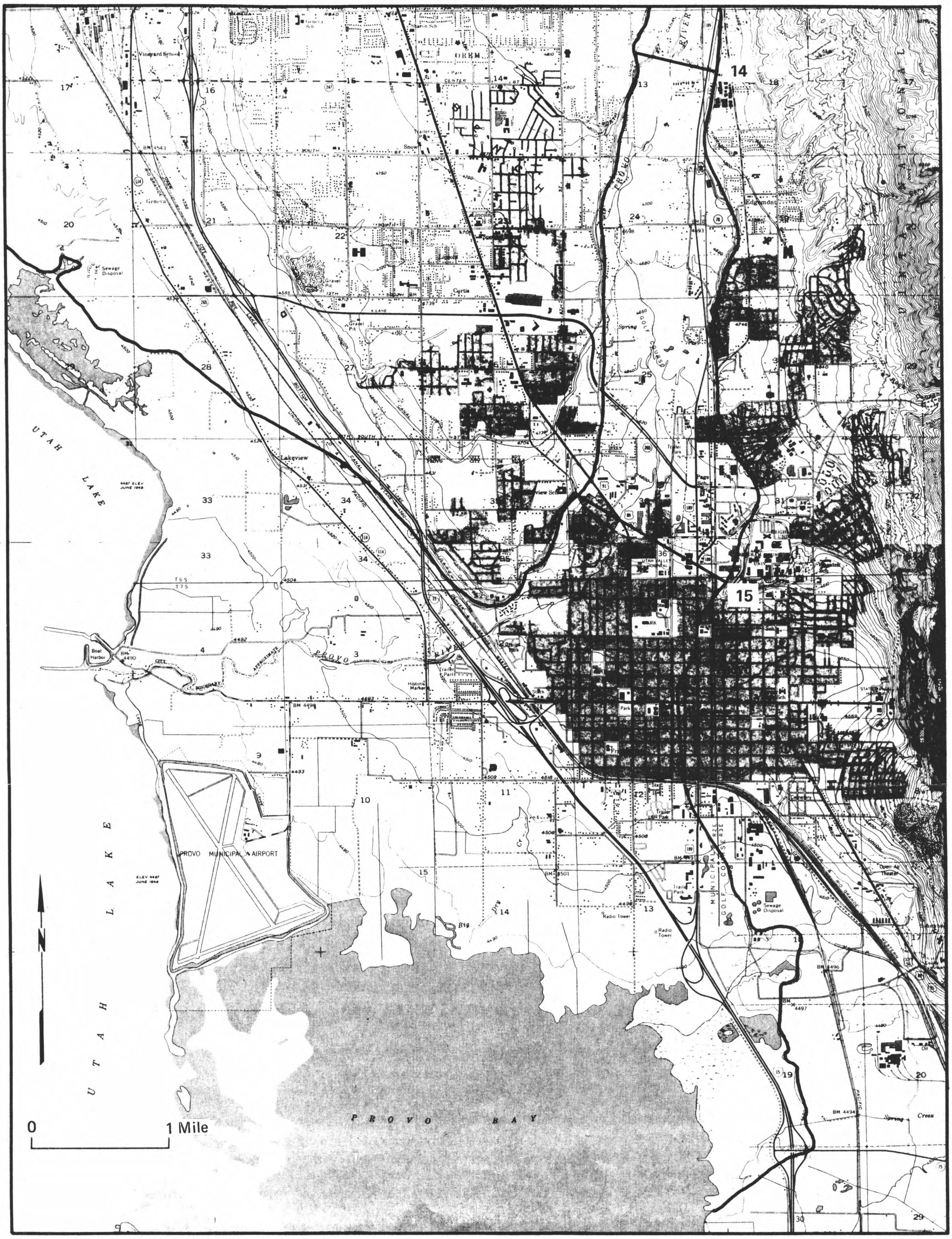
Base from U.S. Geological Survey topographic quadrangles Aspen Grove and Bridal Veil Falls.

PLATE 1. INUNDATED AREA RESULTING FROM A POSTULATED WORST-CASE SCENARIO DEER CREEK DAM FAILURE, PROVO RIVER, UTAH

EXPLANATION

approximate limit of flooding

2 cross-section number



Base from U.S. Geological Survey topographic quadrangles Orem and Provo.

PLATE 1: (continued) INUNDATED AREA RESULTING FROM A POSTULATED WORST-CASE SCENARIO DEER CREEK DAM FAILURE, PROVO RIVER, UTAH

EXPLANATION

approximate limit of flooding

2 cross-section number